US009490646B2

(12) **United States Patent**
Kubota et al.

(10) **Patent No.: US 9,490,646 B2**
(45) **Date of Patent: Nov. 8, 2016**

(54) **DEVICE FOR CONTROLLING ASSEMBLED BATTERY**

(75) Inventors: **Tomoya Kubota**, Yokohama (JP); **Yasuhito Miyazaki**, Yokohama (JP); **Yukinari Kato**, Yokohama (JP); **Yoshio Shimoida**, Yokosuka (JP)

(73) Assignee: **NISSAN MOTOR CO., LTD.**, Yokohama-Shi (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 664 days.

(21) Appl. No.: **13/885,134**

(22) PCT Filed: **Dec. 9, 2010**

(86) PCT No.: **PCT/JP2010/072074**

§ 371 (c)(1),
(2), (4) Date: **May 13, 2013**

(87) PCT Pub. No.: **WO2012/066688**

PCT Pub. Date: **May 24, 2012**

(65) **Prior Publication Data**

US 2013/0234672 A1 Sep. 12, 2013

(30) **Foreign Application Priority Data**

Nov. 17, 2010 (JP) 2010-257194
Dec. 7, 2010 (JP) 2010-272252

(51) **Int. Cl.**
H02J 7/00 (2006.01)
G01N 27/416 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H02J 7/007*** (2013.01); ***H01M 10/4207*** (2013.01); ***H02J 7/0016*** (2013.01); *G01R 31/362* (2013.01); *G01R 31/3658* (2013.01); *Y02T 10/7055* (2013.01)

(58) **Field of Classification Search**
USPC 320/134
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,366,054 B1 * 4/2002 Hoenig G01R 31/3631 320/132
6,611,128 B2 8/2003 Minamiura et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP 62-100670 A 5/1987
JP 2003-204627 A 7/2003
(Continued)

OTHER PUBLICATIONS

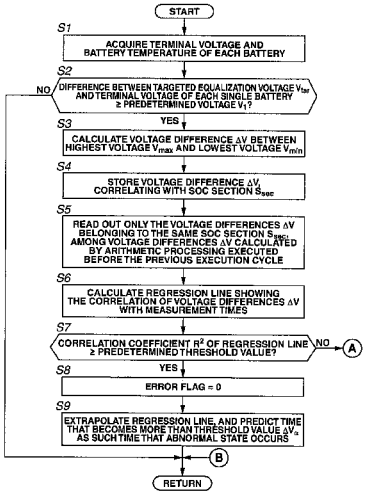
Korean Office Action, Apr. 14, 2014, 4 pages.

Primary Examiner — Richard Isla Rodas
Assistant Examiner — David V Henze-Gongola
(74) *Attorney, Agent, or Firm* — Foley & Lardner LLP

(57) **ABSTRACT**

In a device for controlling an assembled battery provided with a plurality of single batteries, the device includes a capacity adjustment section for adjusting a capacity such that voltages of the single batteries are equalized at a targeted voltage, an internal state detection section for detecting terminal voltages or SOC of the single batteries and for detecting, based on the detected terminal voltages/SOC, a voltage/SOC difference among the single batteries as voltage-difference/SOC-difference data, and a time-series data storage for storing the voltage-difference/SOC-difference data in time-series. Also provided is a prediction section for more appropriately predicting time when the assembled battery becomes an abnormal state, based on a time-dependent change in the voltage-difference/SOC-difference data detected in a voltage/SOC region different from the targeted voltage by a predetermined voltage, among the stored time-series voltage-difference/SOC-difference data.

32 Claims, 15 Drawing Sheets



(51) **Int. Cl.**
H01M 10/42 (2006.01)
G01R 31/36 (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,759,832	B2	7/2004	Minamiura et al.	
7,557,584	B2	7/2009	Murakami et al.	
7,728,598	B2	6/2010	Murakami et al.	
8,129,944	B2	3/2012	Izumi et al.	
2003/0052646	A1	3/2003	Minamiura et al.	
2004/0257042	A1*	12/2004	Liu	H01M 10/441 320/130
2005/0212482	A1*	9/2005	Nakada	H02J 7/0016 320/120
2009/0130542	A1*	5/2009	Mizoguchi	H01M 10/4207 429/61
2009/0243548	A1*	10/2009	Hoff	H02J 7/0081 320/150
2010/0057385	A1	3/2010	Iida	

FOREIGN PATENT DOCUMENTS

JP	2008-134060	A	6/2008
KR	10-2006-0039445	A	5/2006
KR	10-2009-0117838	A	11/2009

* cited by examiner

FIG.1

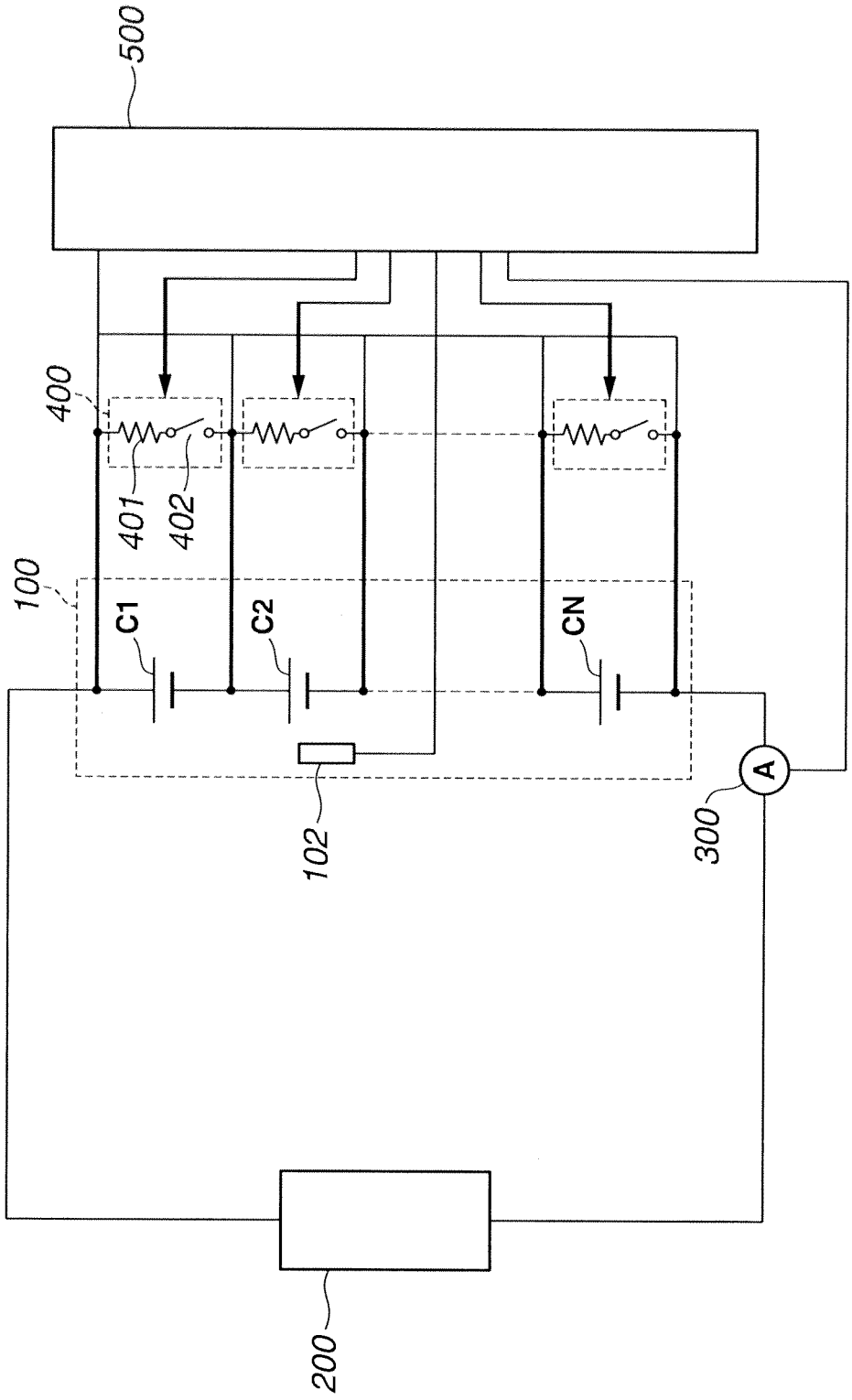


FIG.2

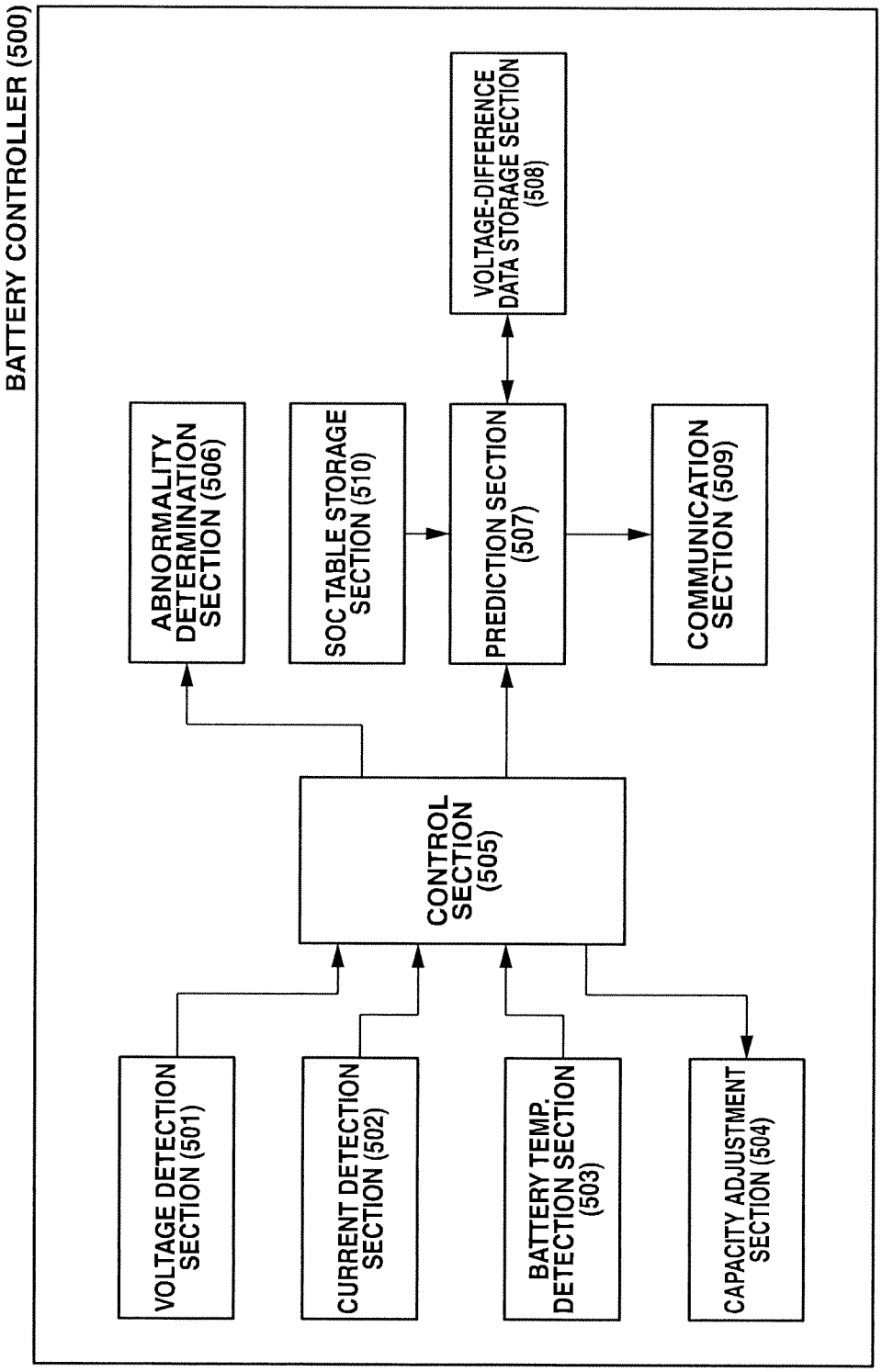

BATTERY CONTROLLER (500)
VOLTAGE-DIFFERENCE DATA STORAGE SECTION (508)
ABNORMALITY DETERMINATION SECTION (506)
SOC TABLE STORAGE SECTION (510)
PREDICTION SECTION (507)
COMMUNICATION SECTION (509)
CONTROL SECTION (505)
VOLTAGE DETECTION SECTION (501)
CURRENT DETECTION SECTION (502)
BATTERY TEMP. DETECTION SECTION (503)
CAPACITY ADJUSTMENT SECTION (504)

FIG.3

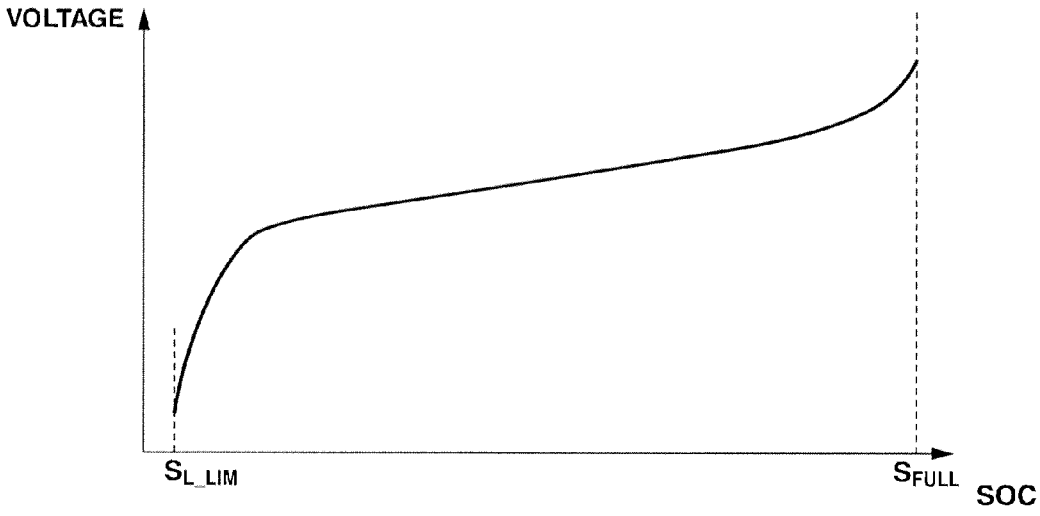


FIG.4

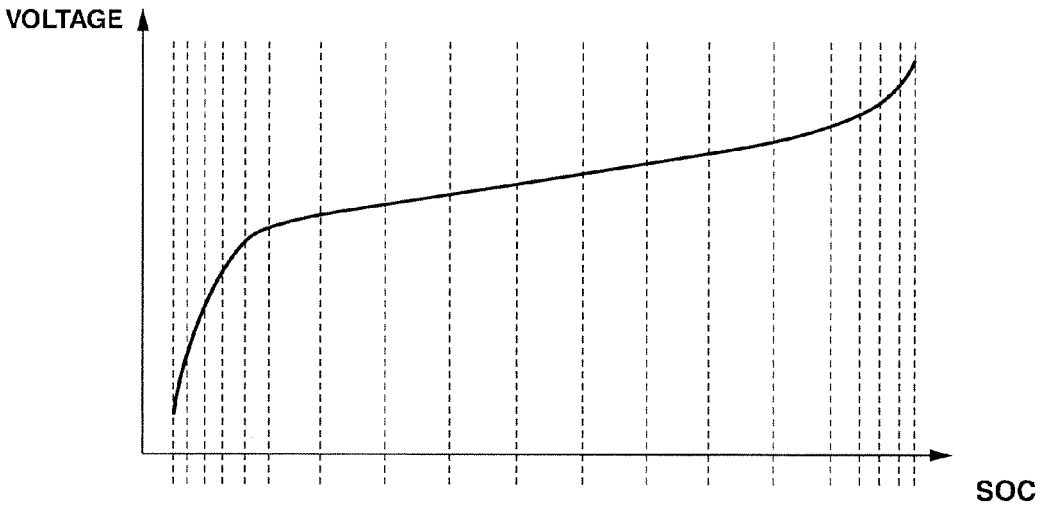


FIG.5

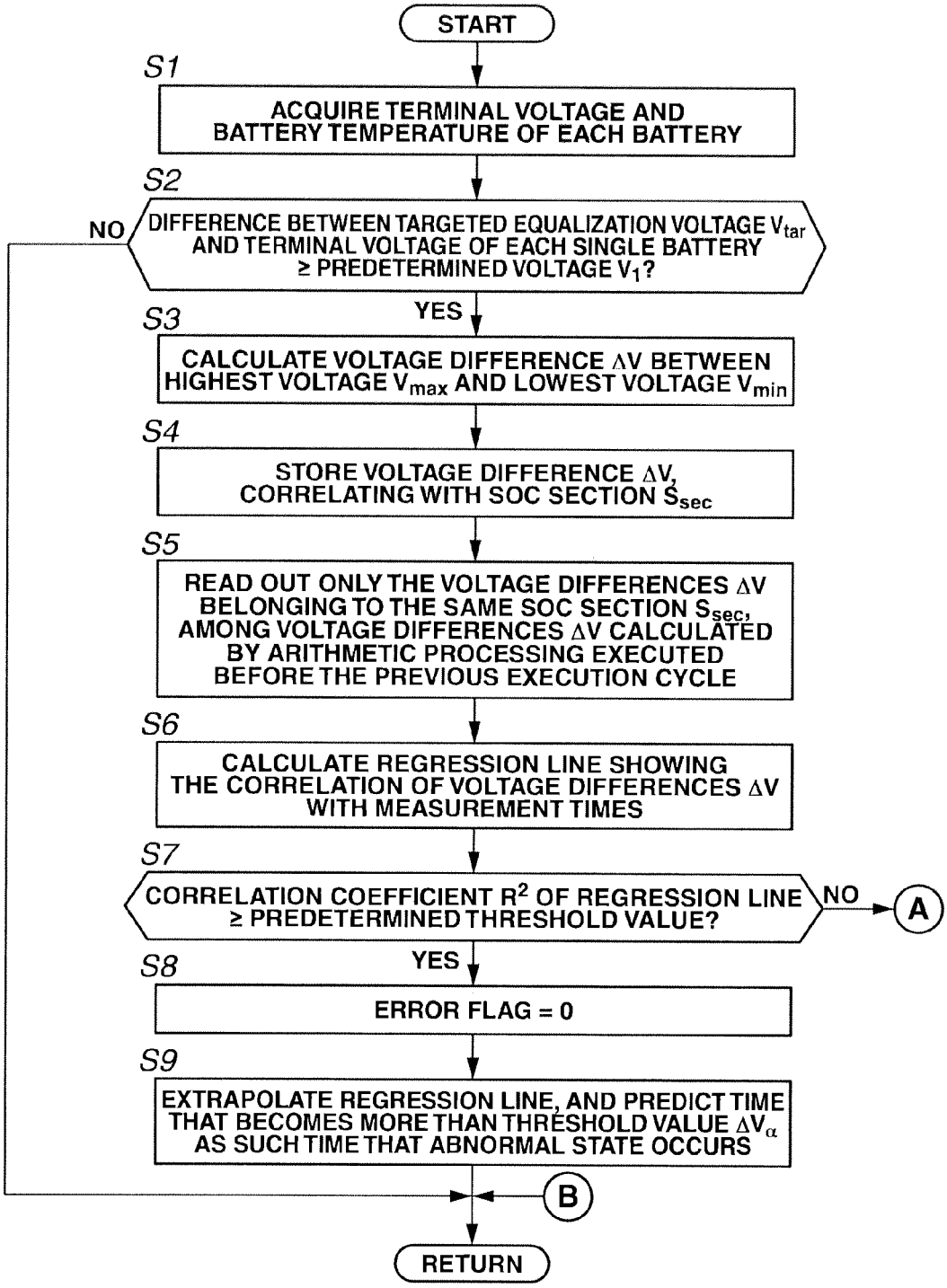

START
S1
ACQUIRE TERMINAL VOLTAGE AND BATTERY TEMPERATURE OF EACH BATTERY
S2
DIFFERENCE BETWEEN TARGETED EQUALIZATION VOLTAGE V_{tar} AND TERMINAL VOLTAGE OF EACH SINGLE BATTERY ≥ PREDETERMINED VOLTAGE V_1?
NO
YES
S3
CALCULATE VOLTAGE DIFFERENCE ΔV BETWEEN HIGHEST VOLTAGE V_{max} AND LOWEST VOLTAGE V_{min}
S4
STORE VOLTAGE DIFFERENCE ΔV, CORRELATING WITH SOC SECTION S_{sec}
S5
READ OUT ONLY THE VOLTAGE DIFFERENCES ΔV BELONGING TO THE SAME SOC SECTION S_{sec}, AMONG VOLTAGE DIFFERENCES ΔV CALCULATED BY ARITHMETIC PROCESSING EXECUTED BEFORE THE PREVIOUS EXECUTION CYCLE
S6
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF VOLTAGE DIFFERENCES ΔV WITH MEASUREMENT TIMES
S7
CORRELATION COEFFICIENT R^2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
NO
A
YES
S8
ERROR FLAG = 0
S9
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN THRESHOLD VALUE ΔV_α AS SUCH TIME THAT ABNORMAL STATE OCCURS
B
RETURN

FIG.6

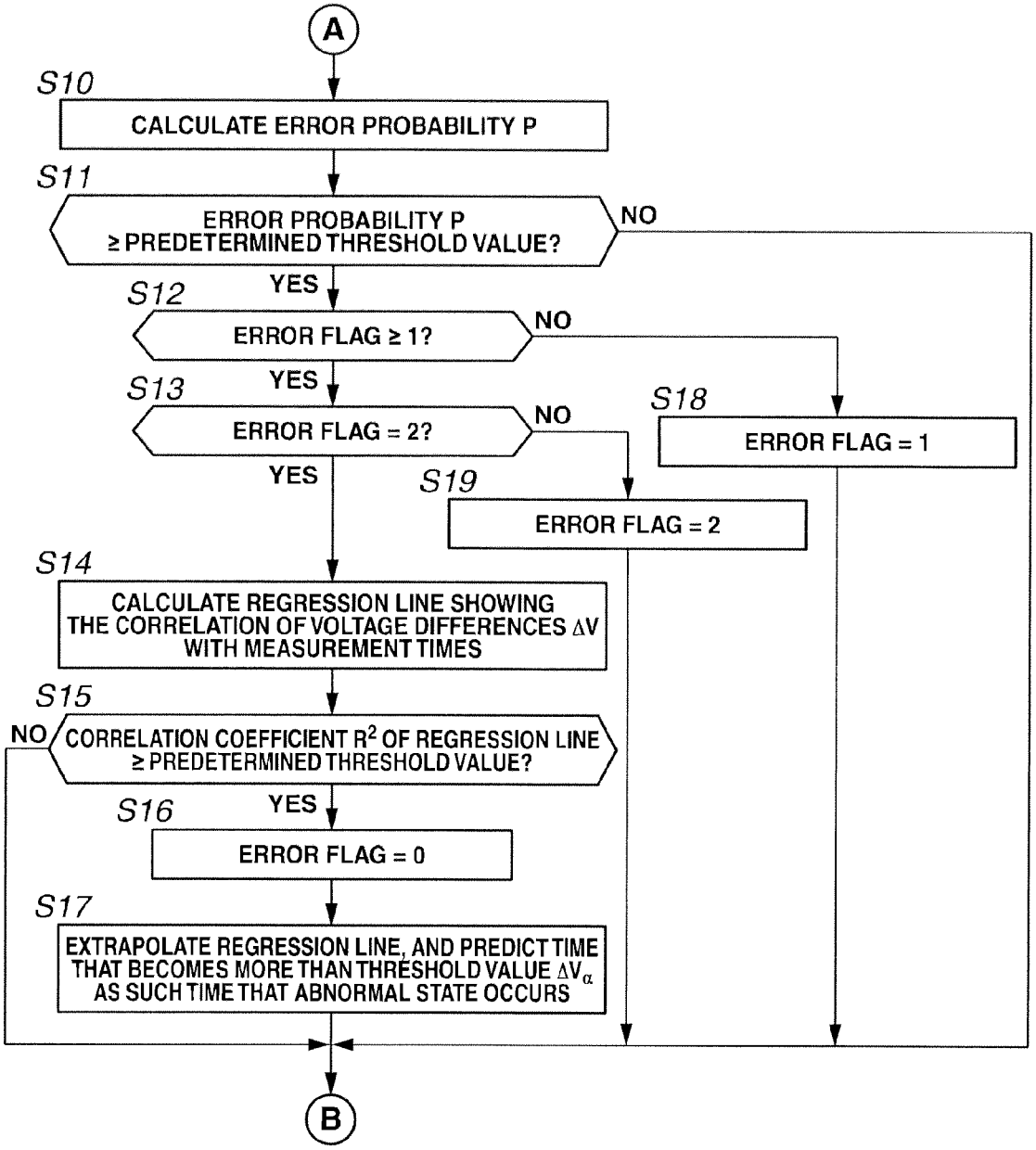

A
S10
CALCULATE ERROR PROBABILITY P
S11
ERROR PROBABILITY P ≥ PREDETERMINED THRESHOLD VALUE?
NO
YES
S12
ERROR FLAG ≥ 1?
NO
YES
S13
ERROR FLAG = 2?
NO
YES
S18
ERROR FLAG = 1
S19
ERROR FLAG = 2
S14
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF VOLTAGE DIFFERENCES ΔV WITH MEASUREMENT TIMES
S15
NO
CORRELATION COEFFICIENT R^2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
S16
YES
ERROR FLAG = 0
S17
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN THRESHOLD VALUE ΔV_α AS SUCH TIME THAT ABNORMAL STATE OCCURS
B

FIG.7

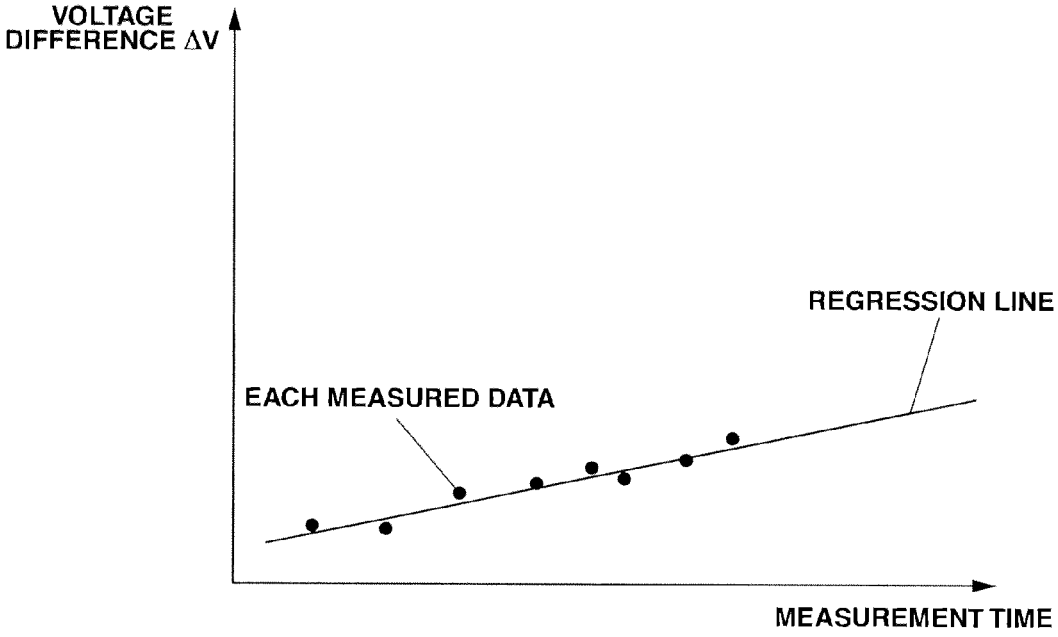

VOLTAGE
DIFFERENCE ΔV
REGRESSION LINE
EACH MEASURED DATA
MEASUREMENT TIME

FIG.8

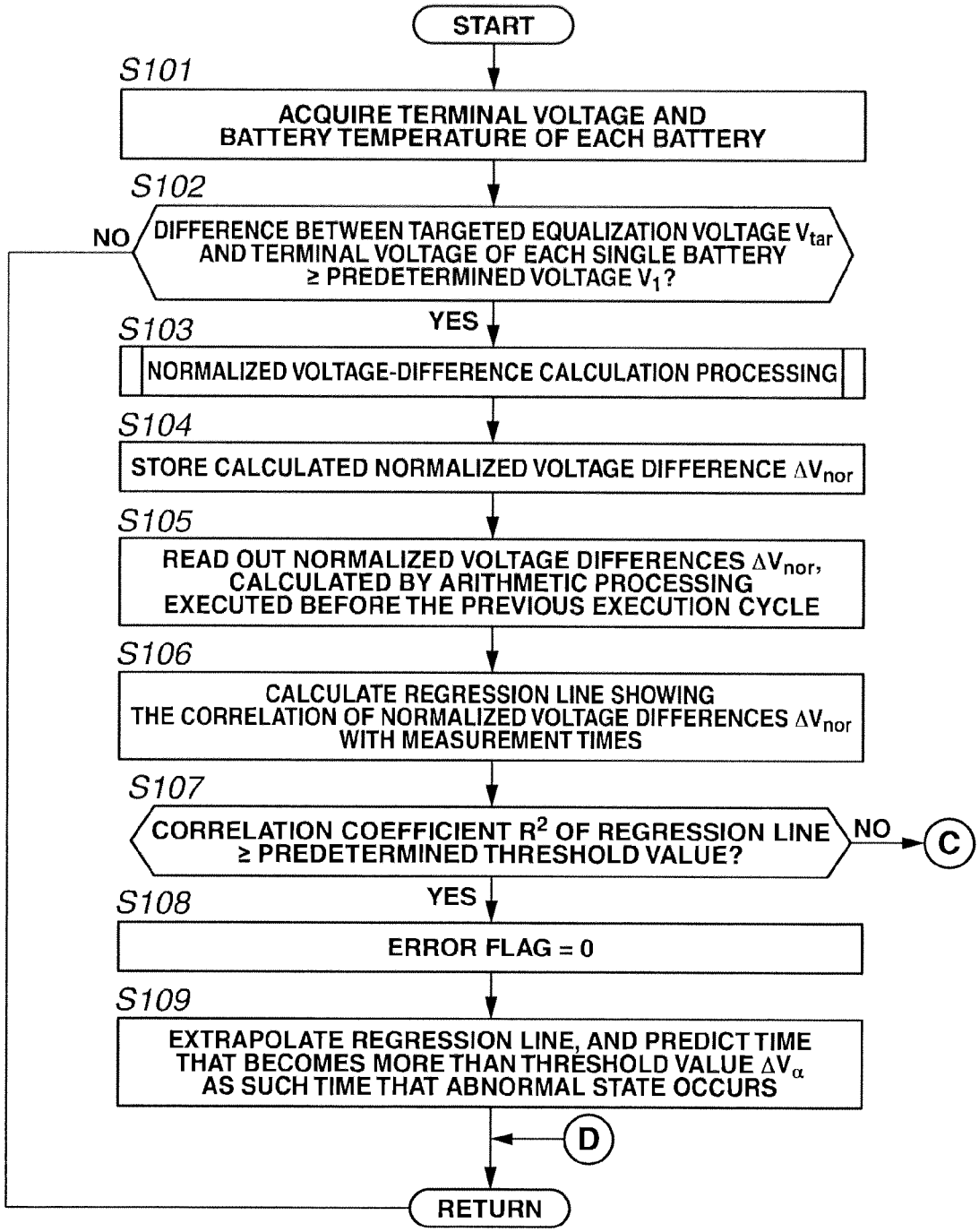

START
S101
ACQUIRE TERMINAL VOLTAGE AND BATTERY TEMPERATURE OF EACH BATTERY
S102
NO
DIFFERENCE BETWEEN TARGETED EQUALIZATION VOLTAGE V_{tar} AND TERMINAL VOLTAGE OF EACH SINGLE BATTERY ≥ PREDETERMINED VOLTAGE V_1?
YES
S103
NORMALIZED VOLTAGE-DIFFERENCE CALCULATION PROCESSING
S104
STORE CALCULATED NORMALIZED VOLTAGE DIFFERENCE ΔV_{nor}
S105
READ OUT NORMALIZED VOLTAGE DIFFERENCES ΔV_{nor}, CALCULATED BY ARITHMETIC PROCESSING EXECUTED BEFORE THE PREVIOUS EXECUTION CYCLE
S106
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF NORMALIZED VOLTAGE DIFFERENCES ΔV_{nor} WITH MEASUREMENT TIMES
S107
CORRELATION COEFFICIENT R^2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
NO
C
YES
S108
ERROR FLAG = 0
S109
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN THRESHOLD VALUE ΔV_α AS SUCH TIME THAT ABNORMAL STATE OCCURS
D
RETURN

FIG.9

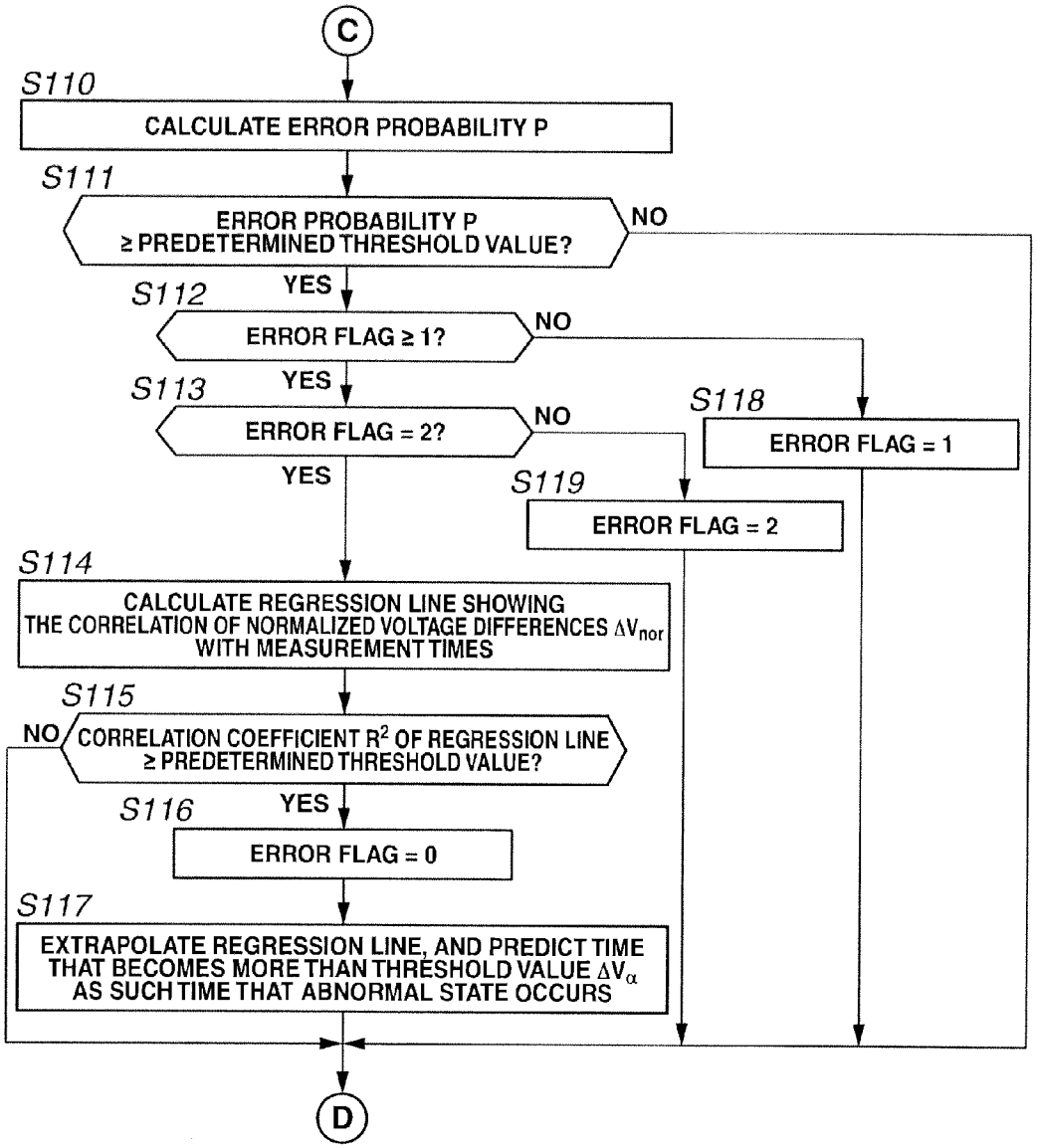

C
S110
CALCULATE ERROR PROBABILITY P
S111
ERROR PROBABILITY P ≥ PREDETERMINED THRESHOLD VALUE?
NO
YES
S112
ERROR FLAG ≥ 1?
NO
YES
S113
ERROR FLAG = 2?
NO
YES
S118
ERROR FLAG = 1
S119
ERROR FLAG = 2
S114
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF NORMALIZED VOLTAGE DIFFERENCES ΔVnor WITH MEASUREMENT TIMES
S115
NO
CORRELATION COEFFICIENT R2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
S116
YES
ERROR FLAG = 0
S117
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN THRESHOLD VALUE ΔVα AS SUCH TIME THAT ABNORMAL STATE OCCURS
D

FIG.10

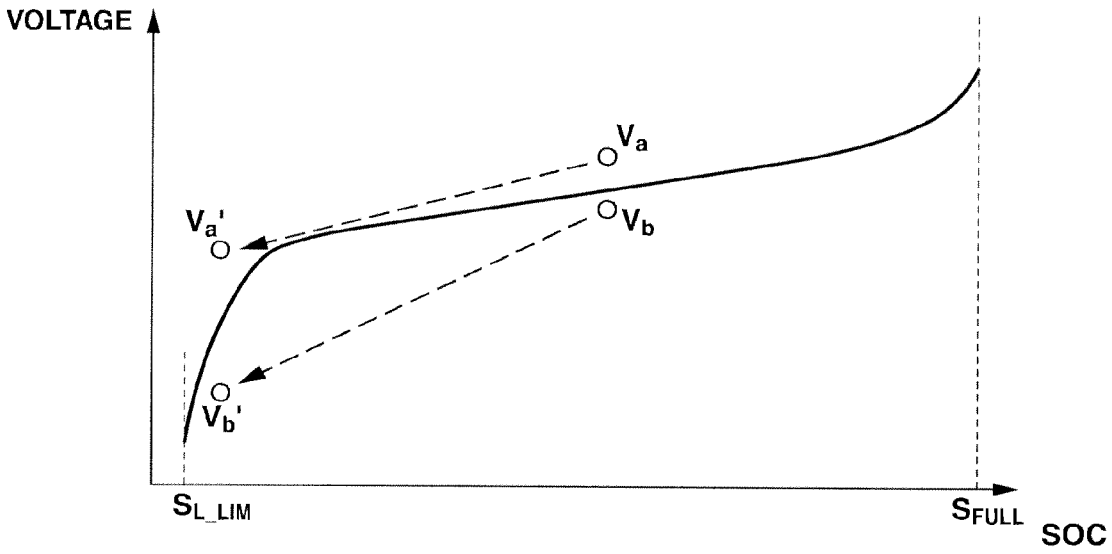


FIG.11

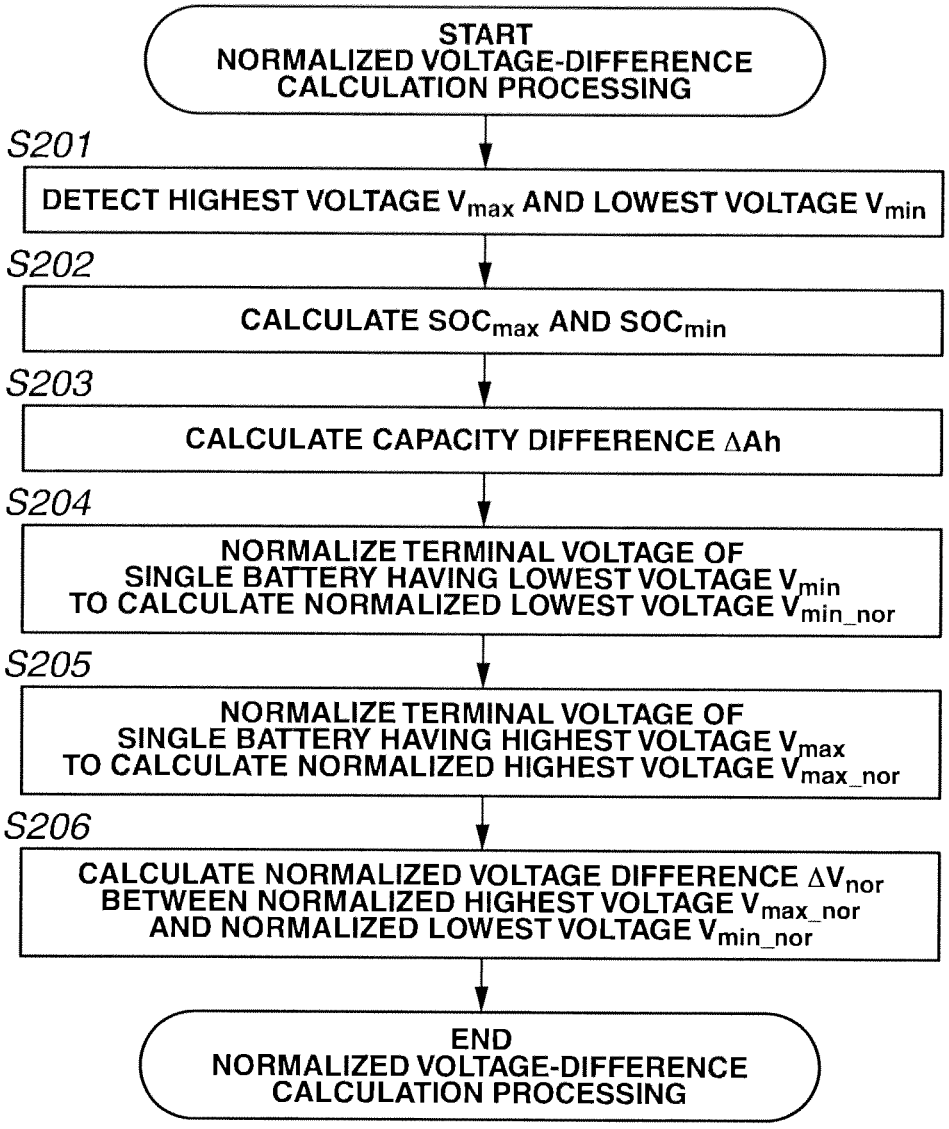

START
NORMALIZED VOLTAGE-DIFFERENCE
CALCULATION PROCESSING
S201
DETECT HIGHEST VOLTAGE V_{max} AND LOWEST VOLTAGE V_{min}
S202
CALCULATE SOC_{max} AND SOC_{min}
S203
CALCULATE CAPACITY DIFFERENCE ΔAh
S204
NORMALIZE TERMINAL VOLTAGE OF
SINGLE BATTERY HAVING LOWEST VOLTAGE V_{min}
TO CALCULATE NORMALIZED LOWEST VOLTAGE V_{min_nor}
S205
NORMALIZE TERMINAL VOLTAGE OF
SINGLE BATTERY HAVING HIGHEST VOLTAGE V_{max}
TO CALCULATE NORMALIZED HIGHEST VOLTAGE V_{max_nor}
S206
CALCULATE NORMALIZED VOLTAGE DIFFERENCE ΔV_{nor}
BETWEEN NORMALIZED HIGHEST VOLTAGE V_{max_nor}
AND NORMALIZED LOWEST VOLTAGE V_{min_nor}
END
NORMALIZED VOLTAGE-DIFFERENCE
CALCULATION PROCESSING

FIG.12

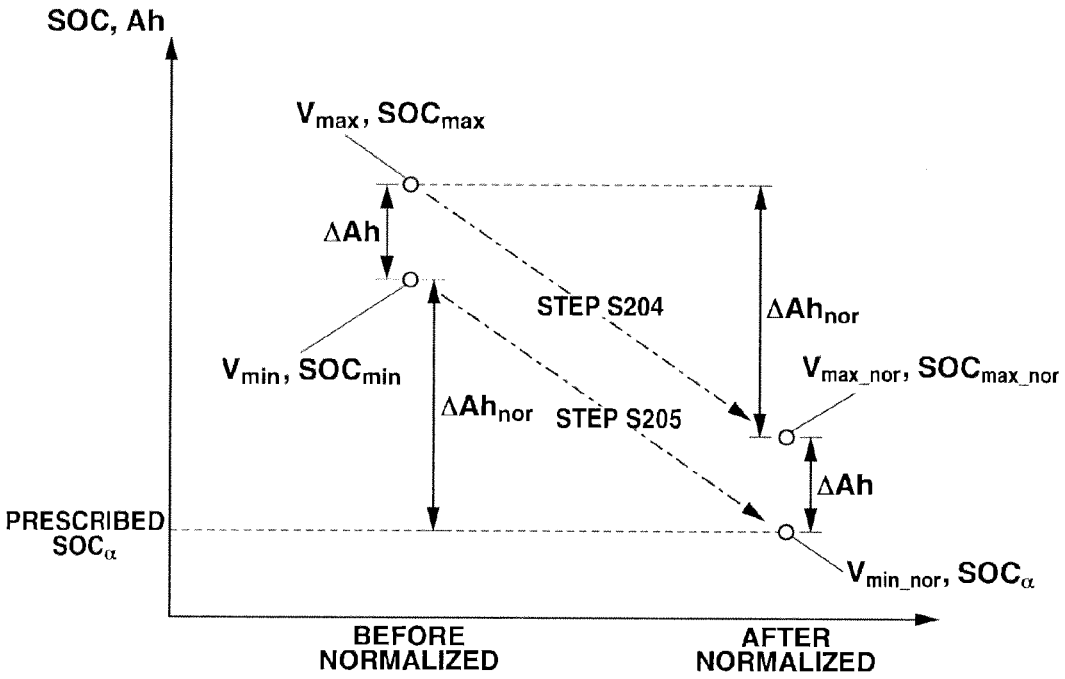

SOC, Ah
V_{max}, SOC_{max}
ΔAh
STEP S204
ΔAh_{nor}
V_{min}, SOC_{min}
V_{max_nor}, SOC_{max_nor}
ΔAh_{nor}
STEP S205
ΔAh
PRESCRIBED SOC_{α}
V_{min_nor}, SOC_{α}
BEFORE NORMALIZED
AFTER NORMALIZED

FIG.13

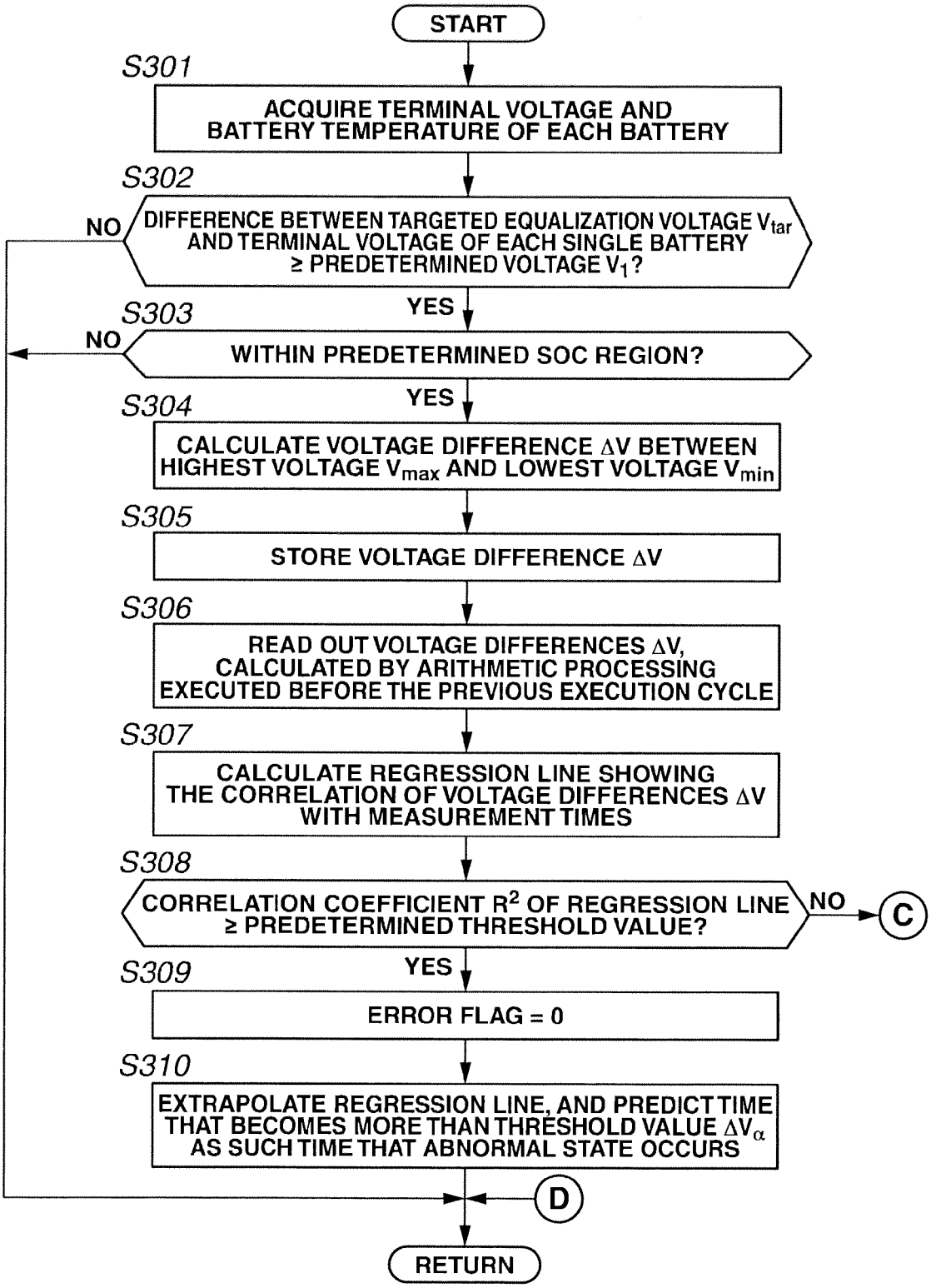

START
S301
ACQUIRE TERMINAL VOLTAGE AND BATTERY TEMPERATURE OF EACH BATTERY
S302
DIFFERENCE BETWEEN TARGETED EQUALIZATION VOLTAGE V_{tar} AND TERMINAL VOLTAGE OF EACH SINGLE BATTERY ≥ PREDETERMINED VOLTAGE V_1?
NO
YES
S303
WITHIN PREDETERMINED SOC REGION?
NO
YES
S304
CALCULATE VOLTAGE DIFFERENCE ΔV BETWEEN HIGHEST VOLTAGE V_{max} AND LOWEST VOLTAGE V_{min}
S305
STORE VOLTAGE DIFFERENCE ΔV
S306
READ OUT VOLTAGE DIFFERENCES ΔV, CALCULATED BY ARITHMETIC PROCESSING EXECUTED BEFORE THE PREVIOUS EXECUTION CYCLE
S307
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF VOLTAGE DIFFERENCES ΔV WITH MEASUREMENT TIMES
S308
CORRELATION COEFFICIENT R^2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
NO
C
YES
S309
ERROR FLAG = 0
S310
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN THRESHOLD VALUE ΔV_α AS SUCH TIME THAT ABNORMAL STATE OCCURS
D
RETURN

FIG.14

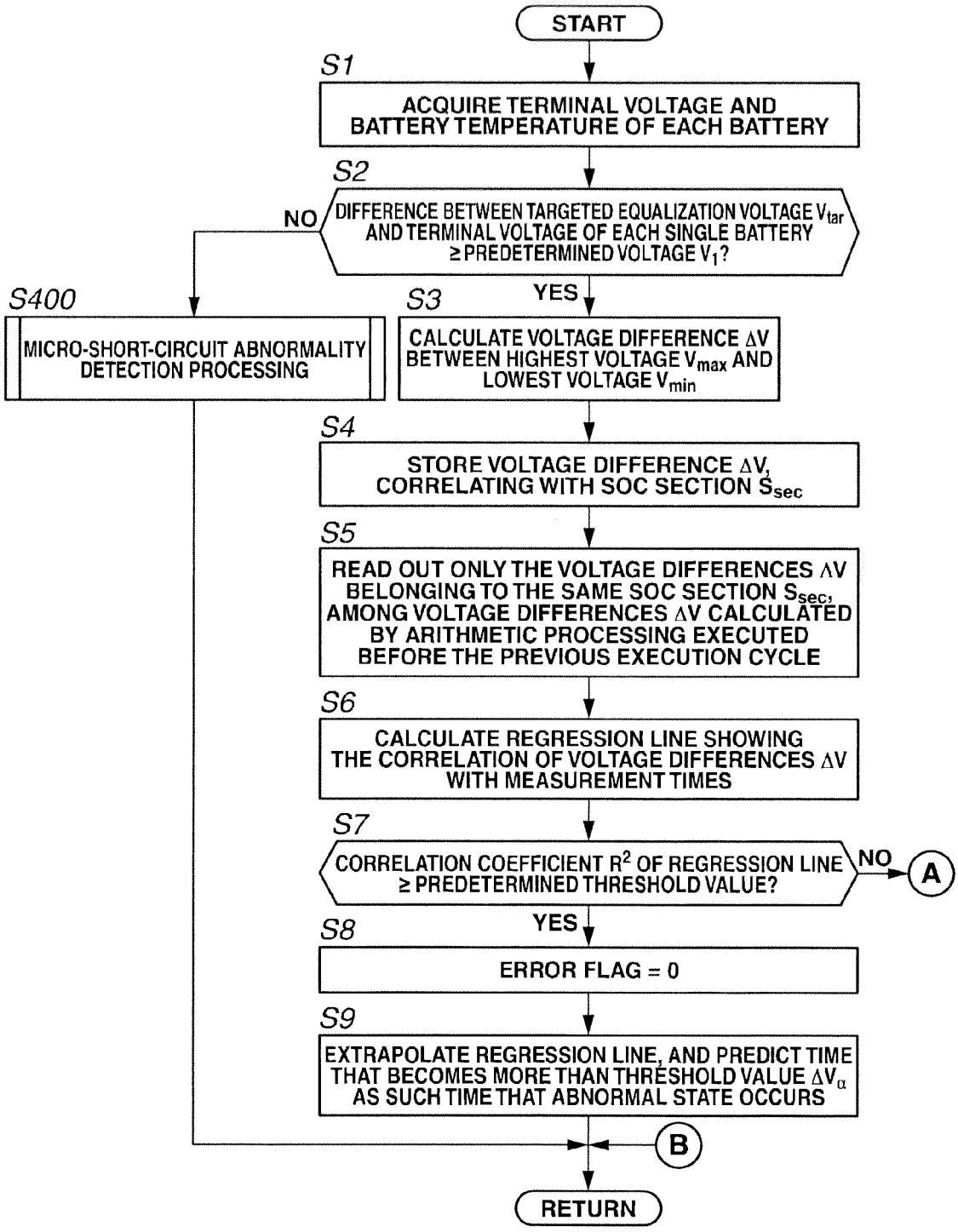

START
S1
ACQUIRE TERMINAL VOLTAGE AND BATTERY TEMPERATURE OF EACH BATTERY
S2
DIFFERENCE BETWEEN TARGETED EQUALIZATION VOLTAGE V_{tar} AND TERMINAL VOLTAGE OF EACH SINGLE BATTERY ≥ PREDETERMINED VOLTAGE V_1?
NO
YES
S400
MICRO-SHORT-CIRCUIT ABNORMALITY DETECTION PROCESSING
S3
CALCULATE VOLTAGE DIFFERENCE ΔV BETWEEN HIGHEST VOLTAGE V_{max} AND LOWEST VOLTAGE V_{min}
S4
STORE VOLTAGE DIFFERENCE ΔV, CORRELATING WITH SOC SECTION S_{sec}
S5
READ OUT ONLY THE VOLTAGE DIFFERENCES ΔV BELONGING TO THE SAME SOC SECTION S_{sec}, AMONG VOLTAGE DIFFERENCES ΔV CALCULATED BY ARITHMETIC PROCESSING EXECUTED BEFORE THE PREVIOUS EXECUTION CYCLE
S6
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF VOLTAGE DIFFERENCES ΔV WITH MEASUREMENT TIMES
S7
CORRELATION COEFFICIENT R^2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
NO
A
YES
S8
ERROR FLAG = 0
S9
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN THRESHOLD VALUE ΔV_α AS SUCH TIME THAT ABNORMAL STATE OCCURS
B
RETURN

FIG.15

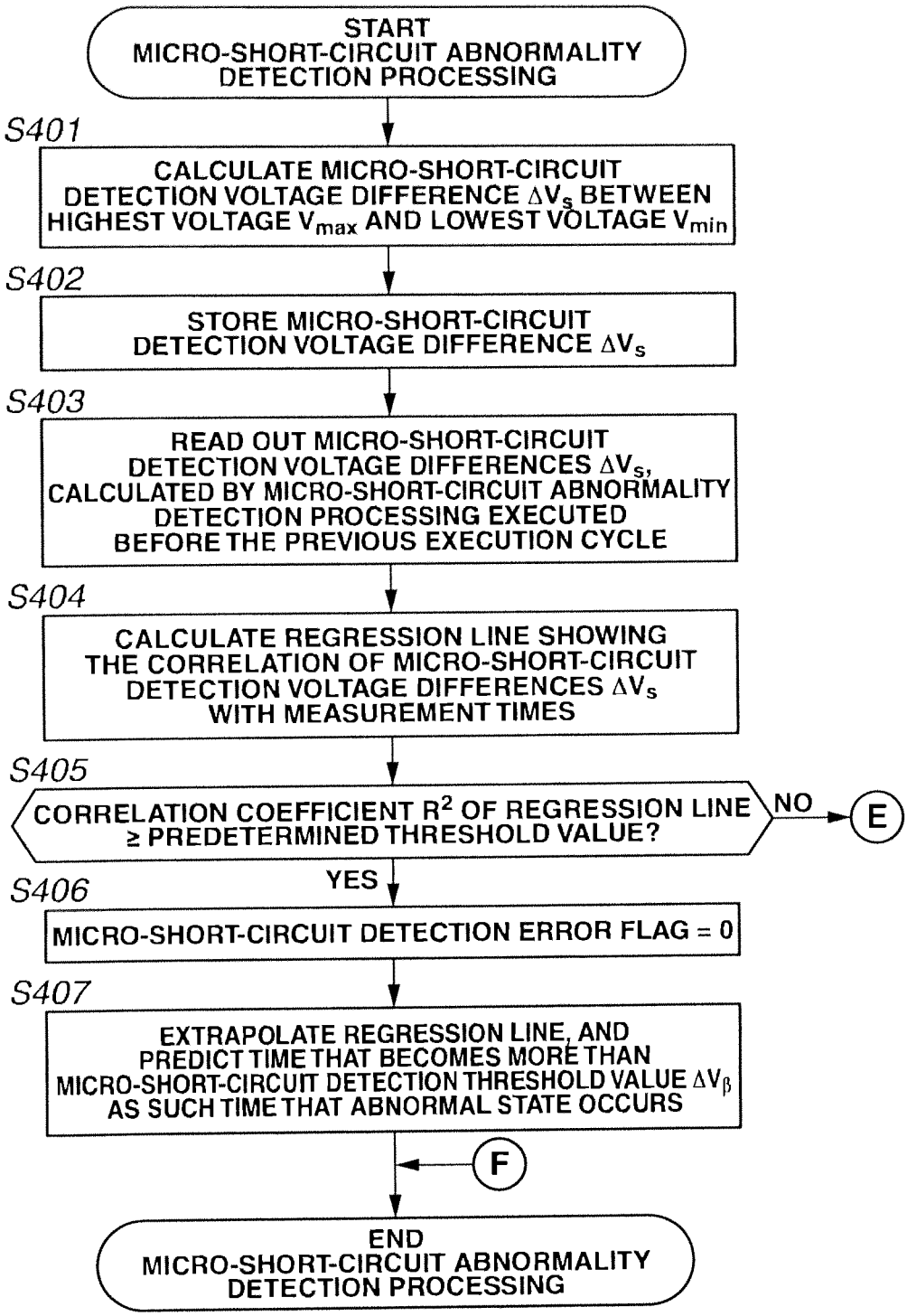
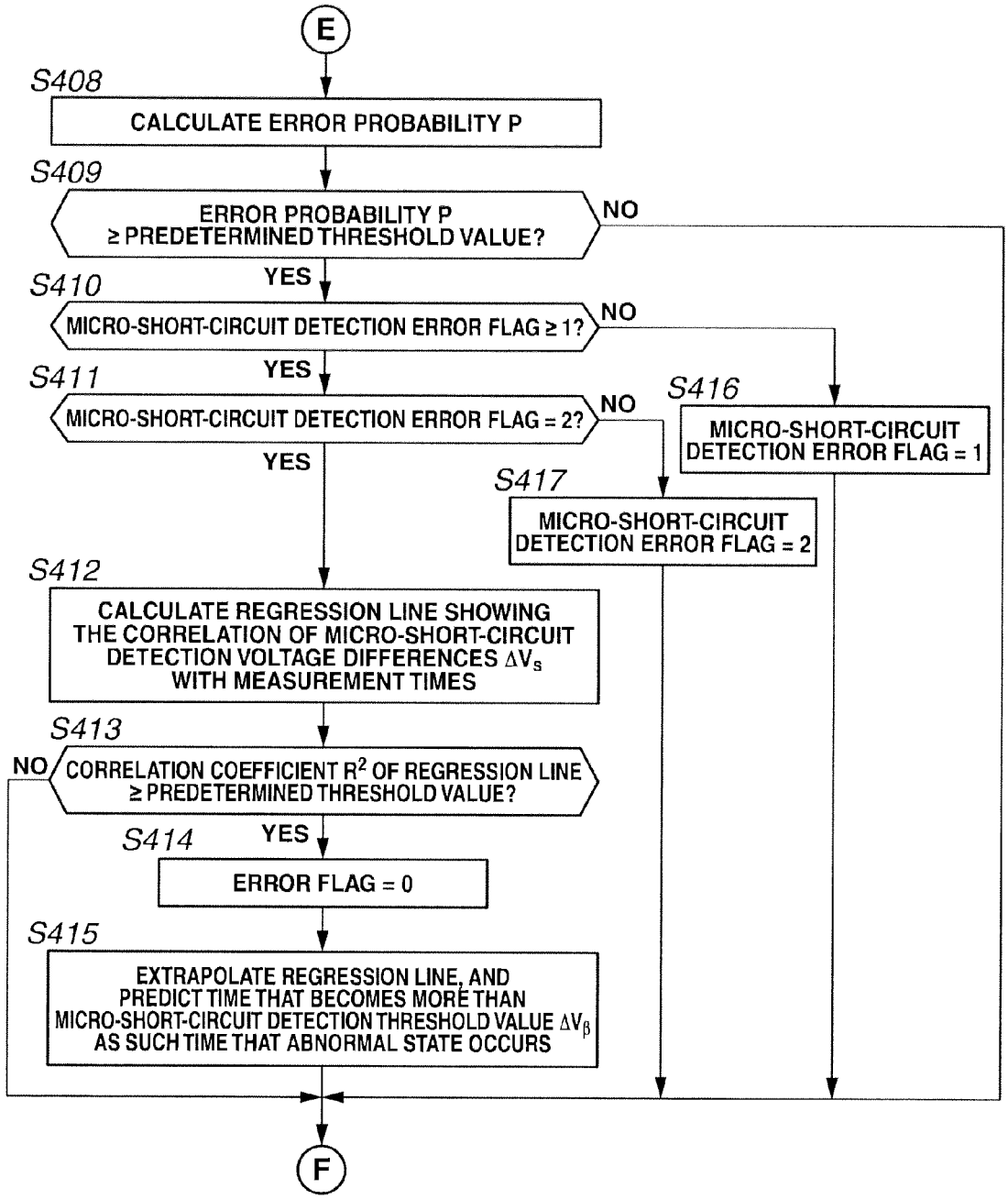

START
MICRO-SHORT-CIRCUIT ABNORMALITY
DETECTION PROCESSING
S401
CALCULATE MICRO-SHORT-CIRCUIT
DETECTION VOLTAGE DIFFERENCE ΔVs BETWEEN
HIGHEST VOLTAGE Vmax AND LOWEST VOLTAGE Vmin
S402
STORE MICRO-SHORT-CIRCUIT
DETECTION VOLTAGE DIFFERENCE ΔVs
S403
READ OUT MICRO-SHORT-CIRCUIT
DETECTION VOLTAGE DIFFERENCES ΔVs,
CALCULATED BY MICRO-SHORT-CIRCUIT ABNORMALITY
DETECTION PROCESSING EXECUTED
BEFORE THE PREVIOUS EXECUTION CYCLE
S404
CALCULATE REGRESSION LINE SHOWING
THE CORRELATION OF MICRO-SHORT-CIRCUIT
DETECTION VOLTAGE DIFFERENCES ΔVs
WITH MEASUREMENT TIMES
S405
CORRELATION COEFFICIENT R2 OF REGRESSION LINE
≥ PREDETERMINED THRESHOLD VALUE?
NO
E
YES
S406
MICRO-SHORT-CIRCUIT DETECTION ERROR FLAG = 0
S407
EXTRAPOLATE REGRESSION LINE, AND
PREDICT TIME THAT BECOMES MORE THAN
MICRO-SHORT-CIRCUIT DETECTION THRESHOLD VALUE ΔVβ
AS SUCH TIME THAT ABNORMAL STATE OCCURS
F
END
MICRO-SHORT-CIRCUIT ABNORMALITY
DETECTION PROCESSING

FIG.16


E
S408
CALCULATE ERROR PROBABILITY P
S409
ERROR PROBABILITY P ≥ PREDETERMINED THRESHOLD VALUE?
NO
YES
S410
MICRO-SHORT-CIRCUIT DETECTION ERROR FLAG ≥ 1?
NO
YES
S411
MICRO-SHORT-CIRCUIT DETECTION ERROR FLAG = 2?
NO
YES
S416
MICRO-SHORT-CIRCUIT DETECTION ERROR FLAG = 1
S417
MICRO-SHORT-CIRCUIT DETECTION ERROR FLAG = 2
S412
CALCULATE REGRESSION LINE SHOWING THE CORRELATION OF MICRO-SHORT-CIRCUIT DETECTION VOLTAGE DIFFERENCES ΔVs WITH MEASUREMENT TIMES
S413
NO
CORRELATION COEFFICIENT R2 OF REGRESSION LINE ≥ PREDETERMINED THRESHOLD VALUE?
S414
YES
ERROR FLAG = 0
S415
EXTRAPOLATE REGRESSION LINE, AND PREDICT TIME THAT BECOMES MORE THAN MICRO-SHORT-CIRCUIT DETECTION THRESHOLD VALUE ΔVβ AS SUCH TIME THAT ABNORMAL STATE OCCURS
F

DEVICE FOR CONTROLLING ASSEMBLED BATTERY

TECHNICAL FIELD

The present invention relates to a device for controlling an assembled battery provided with a plurality of single batteries.

BACKGROUND ART

Regarding an assembled battery provided with a plurality of single batteries, technologies to perform a capacity adjustment of the plurality of single batteries constructing the assembled battery are generally known. For example, Patent document 1 proposes a technology for detecting that the assembled battery is in a state substantially corresponding to an abnormal state when a time interval, during which a capacity adjustment is executed, becomes less than or equal to a predetermined threshold value.

However, in the above-mentioned prior art, in order to detect such an abnormal state of the assembled battery, the time interval, during which the capacity adjustment is executed, has to become less than or equal to the predetermined threshold value. This leads to the problem of a long time needed to detect that the assembled battery is in a state substantially corresponding to an abnormal state. Also, this leads to another problem that it is possible to detect the assembled battery being in a state substantially corresponding to an abnormal state, but it is impossible to predict time when the assembled battery becomes an abnormal state.

A task to be solved by the invention is to appropriately predict time when an assembled battery provided with a plurality of single batteries becomes an abnormal state.

CITATION LIST

Patent Literature

Patent document 1: Japanese patent provisional publication No. 2008-134060 (A)

SUMMARY OF INVENTION

By the invention, the aforementioned task is solved by predicting time when an assembled battery becomes an abnormal state, based on a time-dependent change in voltage-difference data detected in a voltage region different from a targeted voltage, needed to equalize voltages of a plurality of single batteries constructing the assembled battery, by a predetermined voltage or more, or based on a time-dependent change in SOC-difference data detected in a SOC region corresponding to the voltage region.

According to the invention, it is possible to more precisely grasp the tendency of a change in voltage difference or a change in SOC difference, and whereby it is possible to appropriately predict time when the assembled battery becomes an abnormal state.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a system diagram illustrating an assembled battery system according to the invention.

FIG. **2** is a functional block diagram illustrating a battery controller **500**.

FIG. **3** is a table illustrating the relationship between a state of charge (SOC) and a terminal voltage of a lithium-ion battery, which battery is exemplified as one example of a single battery.

FIG. **4** is a diagram showing one example of a SOC-section table illustrating the relationship between the states of battery charge (SOC) and SOC sections S_{sec}.

FIG. **5** is one side of a flowchart illustrating a flow of abnormality-time prediction processing according to a first embodiment.

FIG. **6** is the other of the flowchart illustrating the flow of the abnormality-time prediction processing according to the first embodiment.

FIG. **7** is a diagram showing one example of a regression line, obtained by performing linear regression of the correlation between voltage-difference ΔV data and their measurement times.

FIG. **8** is one side of a flowchart illustrating a flow of abnormality-time prediction processing according to a second embodiment.

FIG. **9** is the other of the flowchart illustrating the flow of the abnormality-time prediction processing according to the second embodiment.

FIG. **10** is an explanatory diagram illustrating the relationship between a SOC region and a voltage difference.

FIG. **11** is a flowchart illustrating a flow of calculation processing for a normalized voltage difference among the single batteries.

FIG. **12** is an explanatory diagram illustrating the calculation processing for the normalized voltage difference.

FIG. **13** is a flowchart illustrating a flow of abnormality-time prediction processing according to a third embodiment.

FIG. **14** is a flowchart illustrating a flow of abnormality-time prediction processing according to a fourth embodiment.

FIG. **15** is one side of a flowchart illustrating a flow of micro-short-circuit abnormality detection processing.

FIG. **16** is the other of the flowchart illustrating the flow of the micro-short-circuit abnormality detection processing.

DESCRIPTION OF EMBODIMENTS

The embodiments according to the invention are hereinafter explained by reference to the drawings.

First Embodiment

FIG. **1** is the system diagram illustrating an assembled battery system of the embodiment. The assembled battery system of the embodiment is hereunder exemplified in a battery for use in an automotive vehicle such as a hybrid vehicle, an electric vehicle or the like.

As shown in FIG. **1**, the assembled battery system of the embodiment is comprised of an assembled battery **100** provided with a plurality of single batteries C**1**, C**2**, . . . , CN, connected in series with each other, a load **200** electrically connected to both ends of the assembled battery **100**, capacity adjustment circuits **400** for adjusting a capacity of the assembled battery **100**, and a battery controller **500** for controlling the whole assembled battery system.

Assembled battery **10** is constructed by connecting single batteries C**1**, C**2**, . . . , CN, whose number N is an integer, in series. An alkaline storage battery such as a nickel-hydrogen battery cell or an organic electrolyte secondary battery such as a lithium-ion battery cell can be used as each single battery C**1**, C**2**, . . . , CN. In the shown embodiment, a lithium-ion battery cell is used or exemplified as each of

the single batteries C1, C2, . . . , CN. As each of the single batteries C1, C2, . . . , CN, a plurality of battery cells, which are connected in parallel and regarded as a single battery, and whose measurable terminal voltage becomes the same, may be included. By the way, the number N of the single batteries is not limited. As necessary, the number of the single batteries can be set suitably. The assembled battery **100** is also equipped with a temperature sensor **102** for measuring a temperature of the single batteries C1, C2, . . . , CN. A battery temperature, measured by the temperature sensor **102**, is sent to the battery controller **500**.

Capacity adjustment circuits **400** are parallel-connected with the respective single batteries C1, C2, . . . , CN, constructing the assembled battery **100**. Each of the capacity adjustment circuits **400** is comprised of an electric resistance **401** and a switch **402**, and configured to enable the single-battery capacity adjustment by performing the capacity-adjustment discharge for the single battery by closing the associated switch **402**. Opening/closing action of each of the switches **402** is controlled by the battery controller **500**.

Load **200** is a motor and an inverter, which are mounted on a hybrid vehicle, an electric vehicle or the like. For instance, when executing regenerative control, the assembled battery **100** can be charged by inverse transformation to electric energy via the motor and the inverter. Also, the assembled battery **100** can be charged by connecting it to an external power source (not shown).

FIG. **2** is the functional block diagram illustrating the battery controller **500**. As shown in FIG. **2**, the battery controller **500** is comprised of a voltage detection section **501**, an electric-current detection section **502**, a battery temperature detection section **503**, a capacity adjustment section **504**, a control section **505**, an abnormality determination section **506**, a prediction section **507**, a voltage-difference data storage section **508**, a communication section **509**, and a SOC table storage section **510**.

Voltage detection section **501** measures a terminal voltage of each of the single batteries C1, C2, . . . , CN, constructing the assembled battery **100**, in time-series periodically at predetermined time intervals, via a plurality of terminal lines connected to the respective single batteries, and converts the measured terminal voltage of each of the single batteries from an analogue signal to a digital signal, and sends the converted signal to the control section **505**. For instance, a method for measuring the terminal voltage of each of the single batteries includes a flying-capacitor method.

Current detection section **502** acquires a charge/discharge current, measured by a current sensor **300** periodically at predetermined time intervals, and converts the acquired charge/discharge current from an analogue signal to a digital signal, and sends the converted signal to the control section **505**. For instance, the current sensor **300** can be constructed by a resistive element, a current transformer, or the like.

Battery temperature detection section **503** acquires the temperature of each single battery C1, C2, . . . , CN, measured by the temperature sensor **102** installed on the assembled battery **100** periodically at predetermined time intervals, and converts the acquired temperature of each of the single batteries C1, C2, . . . , CN from an analogue signal to a digital signal, and sends the converted signal to the control section **505**.

Capacity adjustment section **504** controls, responsively to a capacity-adjustment command from the control section **505**, opening/closing action of each of the switches **402** disposed in the respective capacity adjustment circuits **400** when a terminal voltage difference among the single batteries C1, C2, . . . , CN becomes greater than or equal to a predetermined value, thereby performing the capacity adjustment of the assembled battery **100**.

Control section **505** carries out a control by which the capacity adjustment is performed by means of the capacity adjustment section **504**, on the basis of the data indicating the terminal voltage of each of the single batteries, the charge/discharge current, and the battery temperature, respectively received from the voltage detection section **501**, the current detection section **502**, and the battery temperature detection section **503**. Concretely, the control section **505** sets, first of all, a targeted equalization voltage V_{tar}, needed to equalize voltages of the single batteries C1, C2, . . . , CN, constructing the assembled battery **100**. By the way, the targeted equalization voltage V_{tar} is not limited. The targeted equalization voltage can be arbitrarily set. For instance, a given voltage, substantially corresponding to the assembled battery **100** fully charged, can be set as the targeted equalization voltage V_{tar}. In lieu thereof, a predefined voltage, such as a full-charge voltage or a given voltage near the full-charge voltage, may be preset as the targeted equalization voltage V_{tar}. The targeted equalization voltage V_{tar}, set as discussed above, is stored in a memory (not shown) incorporated in the battery controller **500**. Thereafter, the control section **505** finds a maximum voltage value and a minimum voltage value from the terminal voltages of the single batteries C1, C2, . . . , CN, and then calculates a voltage difference between the maximum voltage value and the minimum voltage value. When a predetermined amount of voltage difference has occurred, the control section generates a capacity-adjustment command for executing a control such that voltages of the single batteries C1, C2, . . . , CN, constructing the assembled battery **100**, are equalized at the targeted equalization voltage V_{tar} by means of the capacity adjustment section **504**. The control section sends the generated capacity-adjustment command to the capacity adjustment section **504**.

Then, the capacity adjustment section **504** performs a capacity adjustment responsively to the capacity-adjustment command. Concretely, the capacity adjustment section **504** performs the capacity adjustment by controlling, responsively to the capacity-adjustment command, opening/closing action of each of the switches **402** and by executing a control such that voltages of the single batteries C1, C2, . . . , CN are equalized at the targeted equalization voltage V_{tar}. In lieu thereof, the capacity adjustment section **504** may perform a capacity adjustment so that voltages of the single batteries C1, C2, . . . , CN are adjusted to respective given voltages by controlling, responsively to the capacity-adjustment command, opening/closing action of each of the switches **402**, and thereafter execute a control such that voltages of the single batteries C1, C2, . . . , CN are equalized at the targeted equalization voltage V_{tar} by repeated executions of charging/discharging actions in the assembled battery **100**.

Control section **505** is also configured to send the data indicating the terminal voltage of each of the single batteries, the charge/discharge current, and the battery temperature, respectively received from the voltage detection section **501**, the current detection section **502**, and the battery temperature detection section **503** to both the abnormality determination section **506** and the prediction section **507**.

Abnormality determination section **506** determines whether the assembled battery **100** is in an abnormal state (i.e., a state where use restrictions are required), using the data indicating the terminal voltage of each of the single batteries, the charge/discharge current, and the battery temperature, and sent from the control section **505**. In the

embodiment, a method for determining whether the assembled battery is in an abnormal state is not limited. A well-known method can be used. For instance, absolute values of electric currents charged/discharged in the assembled battery **100** before a given time has expired are integrated or summed, and then the summed value (the total charging/discharging capacity) is acquired as an abnormality criterion value. It is possible to determine an abnormality by determining whether the acquired abnormality criterion value is greater than or equal to a predetermined threshold value.

Prediction section **507** executes abnormality-time prediction processing for predicting, on the basis of the data indicating the terminal voltage of each of the single batteries, the charge/discharge current, and the battery temperature, and sent from the control section **505**, time when the assembled battery **100** becomes an abnormal state. Concretely, the prediction section **507** detects the highest voltage V_{max} of the single battery whose terminal voltage becomes the maximum value of the terminal voltages of the single batteries C**1**, C**2**, . . . , CN and the lowest voltage V_{min} of the single battery whose terminal voltage becomes the minimum value of the terminal voltages of the single batteries. The prediction section calculates a voltage difference ΔV between the highest voltage and the lowest voltage, and executes the abnormality-time prediction processing for predicting time when the assembled battery **100** becomes an abnormal state, using the calculated voltage difference ΔV, and then sends the obtained prediction result to the communication section **509**. Details of the abnormality-time prediction processing of the embodiment are described later. In the embodiment, in predicting time when the assembled battery **100** becomes an abnormal state, for instance, a point of time of the occurrence of a state where use restrictions are required due to a battery capacity fall in one battery, or two or more batteries of the single batteries constructing the assembled battery **100** is utilized as the time when the abnormal state occurs.

Voltage-difference data storage section **508** allows voltage-difference ΔV data, calculated by the prediction section **507**, to be stored in the memory (not shown) incorporated in the battery controller **500**.

Referring now to FIG. **3**, there is shown the table illustrating the relationship between a SOC and a terminal voltage of a lithium-ion battery exemplified as one example of each of the single batteries C**1**, C**2**, . . . , CN. The table is stored in the SOC table storage section **510**. As shown in FIG. **3**, the lithium-ion battery has a property that a ratio of a terminal-voltage change with respect to a SOC change in the battery becomes large in a SOC region near a full charge S_{FULL} and in a SOC region near a discharge lower limit S_{L_LIM}, and becomes small in the other SOC region.

On the other hand, in the embodiment, as shown in FIG. **4**, the entire SOC range from the full charge S_{FULL} to the discharge lower limit S_{L_LIM}, is classified into a plurality of SOC sections S_{sec}. Also, a SOC-section table, illustrating the relationship between such SOC and SOC sections S_{sec}, is predefined, and the SOC-section table is pre-stored in the voltage-difference data storage section **508**. In FIG. **4**, SOC ranges, sectioned by the broken lines correspond to the respective SOC sections S_{sec}. Additionally, in the embodiment, as shown in FIG. **4**, regarding the SOC regions in which the ratio of the terminal-voltage change with respect to the SOC change in the battery becomes large, the SOC range, constructing each of the SOC sections S_{sec}, is set to be narrowed, as the ratio increases. Conversely, regarding the SOC region in which the ratio of the terminal-voltage change with respect to the SOC change in the battery becomes small, the SOC range, constructing each of the SOC sections S_{sec}, is set to be widened, as the ratio decreases.

In the embodiment, when storing voltage-difference ΔV data, calculated by the prediction section **507**, in the memory incorporated in the battery controller **500**, the voltage-difference data storage section **508** determines, by reference to the SOC-section table illustrating the specified relationship shown in FIG. **4**, a SOC section S_{sec}, to which a SOC region, corresponding to each of voltages of the plurality of single batteries C**1**, C**2**, . . . , CN (or the assembled battery **100**) when arithmetic calculation for the voltage-difference ΔV data has been executed, belongs. Then, the voltage-difference data storage section **508** stores the voltage-difference ΔV data, calculated by the prediction section **507**, in the memory incorporated in the battery controller **500**, while correlating with the determined SOC section S_{sec}.

Communication section **509** sends the prediction result of the time when the assembled battery **100** becomes an abnormal state, which result has been obtained by the abnormality-time prediction processing executed within the prediction section **507**, to a wireless communication terminal such as a cellular phone that the user has, or an on-vehicle equipment installed on the vehicle, for informing the user about the prediction result via the wireless communication terminal or the on-vehicle equipment.

Then, the abnormality-time prediction processing of the embodiment, executed within the prediction section **507** of the battery controller **500**, is described in detail. FIGS. **5** and **6** are the flowchart illustrating the flow of abnormality-time prediction processing of the embodiment. The abnormality-time prediction processing, hereinafter described in detail, is initiated when turning on an ignition switch of the vehicle, on which the assembled battery system of the embodiment is mounted, or when powering the vehicle's electrical systems by the charging-on system. The following processing is executed mainly by means of the prediction section **507** of the battery controller **500**.

First, at step S**1**, data acquisition for the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN, and the battery temperature is executed.

Then, at step S**2**, the targeted equalization voltage V_{tar}, set by the control section **505**, is compared to the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN, so as to determine whether the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN is greater than or equal to a predetermined voltage V_1. When the difference between them is greater than or equal to the predetermined voltage V_1, the routine proceeds to step S**3**. Conversely when the difference between them is less than the predetermined voltage V_{11} the current processing terminates and thus the routine returns again to step S**1**. By the way, in the embodiment, in determining about whether the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN is greater than or equal to the predetermined voltage V_1, an affirmative determination that the difference between them is greater than or equal to the predetermined voltage V_1 can be made when the terminal voltages of all of the single batteries C**1**, C**2**, . . . , CN differ from the targeted equalization voltage V_{tar} by the predetermined voltage V_1 or more. However, such a determination is not limited to such a condition. For instance, when the terminal voltage of each of the single batteries more than a predetermined number, among the single batteries C**1**, C**2**, . . . , CN, differs from the targeted

equalization voltage V_{tar} by the predetermined voltage V_1 or more, such a determination that the difference between them is greater than or equal to the predetermined voltage V_1 may be made. Also, the predetermined voltage V_1 is not limited. The predetermined voltage may be set to an arbitrary voltage at which it can be determined that the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN substantially differ from each other. For instance, the predetermined voltage can be set to a voltage value within a voltage range from 1 millivolt to dozens of millivolts.

Then, at step S**3**, the voltage difference ΔV, corresponding to a finite difference among the terminal voltages of the single batteries C**1**, C**2**, . . . , CN, is calculated. Concretely, on the basis of the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN, acquired at step S**1**, detection processing is carried out for detecting both the highest voltage V_{max} of the single battery whose terminal voltage becomes the maximum value and the lowest voltage V_{min} of the single battery whose terminal voltage becomes the minimum value. Thereafter, the voltage difference ΔV is calculated by arithmetically calculating the difference between the highest voltage V_{max} and the lowest voltage V_{min}. Then, the calculated voltage-difference ΔV data is sent to the voltage-difference data storage section **508**.

Then, at step S**4**, the voltage-difference data storage section **508** of the battery controller **500** determines a SOC section S_{sec}, to which a SOC region, corresponding to the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN when arithmetic calculation for the voltage-difference ΔV data has been executed, belongs, from the voltage-difference ΔV data calculated at step S**3** by reference to the SOC-section table illustrating the specified relationship shown in FIG. **4**. Then, the voltage-difference data storage section **508** stores the voltage-difference ΔV data in the memory incorporated in the battery controller **500**, while correlating with the determined SOC section S_{sec}. At this time, the voltage-difference ΔV data, together with the measurement-time data for the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN, used for arithmetic calculation for the voltage difference ΔV, is stored in the memory incorporated in the battery controller **500**, while correlating with the determined SOC section S_{sec}.

Then, at step S**5**, the voltage-difference ΔV data, stored in the memory and calculated by the arithmetic processing executed before the previous execution cycle, is read out. By the way, in the embodiment, when reading out the voltage-difference ΔV data calculated by the arithmetic processing executed before the previous execution cycle, only the voltage-difference ΔV data belonging to the same SOC section S_{sec}, which SOC section is determined at step S**4**, as the voltage difference ΔV calculated by the current arithmetic processing, is read out.

Then, at step S**6**, by performing linear regression of the correlation of the voltage-difference ΔV data calculated by the arithmetic processing executed before the previous execution cycle and belonging to the same SOC section S_{sec} as the voltage difference ΔV calculated by the current arithmetic processing, and the voltage-difference ΔV data calculated by the current arithmetic processing, with the measurement times of these data, a regression line is obtained. FIG. **7** shows one example of the regression line, obtained according to the embodiment. In the embodiment, as shown in FIG. **7**, the measurement time is taken as an x-axis, the voltage-difference ΔV data is taken as a y-axis, and then each of the data is plotted. By performing linear regression of the plotted points, a regression line is obtained. A method for performing linear regression is not limited. For instance, a generally-known method such as a least squares method can be used.

Then, at step S**7**, a correlation coefficient R^2 of the regression line, obtained at step S**6**, is calculated. On the basis of the calculated correlation coefficient R^2, the reliability of the regression line, obtained at step S**6**, is evaluated. When the correlation coefficient R^2 of the regression line is greater than or equal to a predetermined threshold value and thus it is determined that the reliability is enough, the routine proceeds to step S**8**. Conversely when the correlation coefficient R^2 of the regression line is less than the predetermined threshold value, the routine proceeds to step S**10**. By the way, the aforementioned predetermined threshold value can be set or determined depending on whether or not the reliability of the regression line is enough.

When it is determined that the reliability of the regression line, obtained at step S**6**, is enough, the routine proceeds to step S**8**. At step S**8**, an error flag is set to "0", and then the routine proceeds to step S**9**. At step S**9**, on the basis of the regression line obtained at step S**6**, processing for predicting time when the assembled battery **100** becomes an abnormal state is executed. Concretely, extrapolation processing for the regression line, obtained at step S**6**, is executed. Time when the voltage difference ΔV becomes greater than or equal to a predetermined threshold value ΔV_α is calculated from the extrapolated regression line. The calculated time is set as the time when the assembled battery **100** becomes an abnormal state. By the way, in the embodiment, the aforementioned predetermined threshold value ΔV_α can be set to an arbitrary value at which it can be determined that the assembled battery **100** becomes an abnormal state (for example, a state where use restrictions are required due to a battery capacity fall in one or two or more batteries of the single batteries constructing the assembled battery **100**). Information about the time when the assembled battery **100** becomes an abnormal state, which time is predicted or obtained in this way, is sent from the prediction section **507** to the communication section **510**. Then, the information is sent via the communication section **510** to the wireless communication terminal such as a cellular phone that the user has, or the on-vehicle equipment installed on the vehicle, for supplying the information about the time when the assembled battery **100** becomes an abnormal state via the wireless communication terminal or the on-vehicle equipment to the user. In this manner, by supplying the information about the time when the assembled battery **100** becomes an abnormal state to the user, the exchange of some single batteries of the single batteries constructing the assembled battery **100** can be promoted, thereby enabling the longer but safe use of the assembled battery **100** by the user.

The error flag is a flag for determining whether the voltage-difference ΔV data that an error probability P (described later) has become greater than or equal to a predetermined threshold value has occurred. In the embodiment, the error flag is set every SOC sections S_{sec}. That is, in the embodiment, the error flags can be set depending on the number of the SOC sections S_{sec}.

Conversely when step S**7** determines that the correlation coefficient R^2 of the regression line, obtained at step S**6**, is less than the predetermined threshold value and thus the reliability is low, the routine proceeds to step S**10**. At step S**10**, an error probability P of the voltage-difference ΔV data calculated by the current arithmetic processing is calculated. The error probability P is actually calculated by calculating an average value AVE(ΔV) and a standard deviation STDV (ΔV) of the voltage-difference ΔV data calculated by the

arithmetic processing executed before the previous execution cycle and belonging to the same SOC section S_{sec} as the voltage difference ΔV calculated by the current arithmetic processing, and the voltage-difference ΔV data calculated by the current arithmetic processing, and by calculating the difference {ΔV−AVE(ΔV)} between the voltage difference ΔV calculated by the current arithmetic processing and the average value AVE(ΔV), and by calculating a probability density from the difference {ΔV−AVE(ΔV)} and the standard deviation STDV(ΔV).

At step **S11**, a check is made to determine whether the error probability P of the voltage-difference ΔV data calculated by the current arithmetic processing is greater than or equal to the predetermined threshold value. When the error probability P is greater than or equal to the predetermined threshold value, the routine proceeds to step **S12**. Conversely when the error probability P is less than the predetermined threshold value, the current processing terminates and thus the routine returns again to step **S1**. By the way, the predetermined threshold value used in step **S11** is set to an arbitrary value at which it can be determined that the voltage-difference ΔV data calculated by the current arithmetic processing clearly deviates from a distribution of the voltage-difference data ΔV calculated by the arithmetic processing executed before the previous execution cycle.

At step **S12**, a check is made to determine whether the error flag is set to a value greater than or equal to "1". In the shown embodiment, in the case that the error probability P has been calculated by the previous arithmetic processing (see step **S10**) and it has been determined that the error probability P becomes greater than or equal to the predetermined threshold value (see step **S11**), the error flag is set to "1" at step **S18** (described later). When the error flag is set to a value greater than or equal to "1", the routine proceeds to step **S13**. Conversely when the error flag is not set to a value greater than or equal to "1", that is, the error flag is "0", the routine proceeds to step **S18**. At step **S18**, the error flag is set to "1". Then, the current processing terminates and thus the routine returns again to step **S1**.

When the error flag is set to a value greater than or equal to "1", the routine proceeds to step **S13**, at which a check is made to determine whether the error flag is set to "2". In the shown embodiment, in the case that the error probability P has been calculated (see step **S10**) under such a state where the error flag has been set to "1" at the previously-discussed step **S18** at the previous arithmetic processing, and it has been determined that the error probability P becomes greater than or equal to the predetermined threshold value (see step **S11**), the error flag is set to "2" at step **S19** (described later). When the error flag is set to "2", the routine proceeds to step **S14**. Conversely when the error flag is not set to "2", that is, the error flag is "1", the routine proceeds to step **S19**, at which the error flag is set to "2". Then, the current processing terminates without predicting time when the assembled battery **100** becomes an abnormal state, and thus the routine returns again to step **S1**.

That is, in the embodiment, when it has been determined that, regarding the voltage-difference ΔV data belonging to the same SOC section S_{sec}, their error probabilities P become greater than or equal to the predetermined threshold value consecutively three times, the routine proceeds to step **S14**.

At step **S14**, a regression line showing the correlation of the voltage difference ΔV data with their measurement times is calculated in the same manner as the previously-discussed step **S6**, using the consecutive data for three points from the initial voltage-difference ΔV data which have been acquired consecutively three or more times.

At step **S15**, in the same manner as the previously-discussed step **S7**, a correlation coefficient R^2 of the regression line, obtained at step **S14**, is calculated. On the basis of the calculated correlation coefficient R^2, the reliability of the regression line, obtained at step **S14**, is evaluated. When the correlation coefficient R^2 of the regression line is greater than or equal to the predetermined threshold value and thus it is determined that the reliability is enough, the routine proceeds to step **S16**. Conversely when the correlation coefficient R^2 of the regression line is less than the predetermined threshold value, the current processing terminates and thus the routine returns again to step **S1**.

When it is determined that the reliability of the regression line, obtained at step **S14**, is enough, the routine proceeds to step **S16**. At step **S16**, the error flag is set to "0", and then the routine proceeds to step **S17**. At step **S17**, in the same manner as the previously-discussed step **S9**, on the basis of the regression line obtained at step **S14**, processing for predicting time when the assembled battery **100** becomes an abnormal state is executed. Concretely, extrapolation processing for the regression line, obtained at step **S14**, is executed. Time when the voltage difference ΔV becomes greater than or equal to the predetermined threshold value ΔV_α is calculated from the extrapolated regression line. The calculated time is set as the time when the assembled battery **100** becomes an abnormal state. Information about the time when the assembled battery **100** becomes an abnormal state, which time is predicted or obtained in this way, is sent from the prediction section **507** to the communication section **510**. Then, the information is sent via the communication section **510** to the wireless communication terminal such as a cellular phone that the user has, or the on-vehicle equipment installed on the vehicle, for supplying the information about the time when the assembled battery **100** becomes an abnormal state via the wireless communication terminal or the on-vehicle equipment to the user.

By the way, in the case that the previously-discussed processing of steps **S14**-**S17** (hereinafter referred to as "error processing") has been executed, when, at the previously-discussed step **S5** in the arithmetic processing after the next execution cycle, reading out the selected voltage-difference ΔV data of the voltage-difference ΔV data calculated by the arithmetic processing executed before the previous execution cycle, belonging to the same SOC section S_{sec}, while correlating with the measurement time, the voltage-difference ΔV data used by the error processing are read out. Processing for predicting time when the assembled battery **100** becomes an abnormal state is executed, using the read-out data. By the way, in the embodiment, the error flag is set every SOC sections S_{sec}, and the previously-discussed error processing is executed every SOC sections S_{sec}. Thus, in the embodiment, regarding each of the SOC sections S_{sec} that the error processing has been executed, the voltage-difference ΔV data used for the error processing are read out. On the other hand, regarding each of the SOC sections S_{sec} that the error processing has not yet been executed, the voltage-difference ΔV data calculated by the arithmetic processing executed before the previous execution cycle is read out as usual without reading out the voltage-difference ΔV data used for the error processing.

Also, in the case that the previously-discussed step **S15** determines that the correlation coefficient R^2 of the regression line is less than the predetermined threshold value, when, in the processing after the next execution cycle, the error probability P is further calculated (see step **S10**) and

then it is determined that the calculated error probability P is greater than or equal to the predetermined threshold value (see step **S11**), by performing linear regression of the correlation of the consecutive voltage-difference ΔV data for four points (or five points or more) in total, whose error probabilities P become greater than or equal to the predetermined threshold value, with their measurement times, in the same manner as described previously, the regression line is obtained and then the previously-discussed processing of steps **S14**-**S17** is executed. At this time, assuming that, in the processing after the next execution cycle, a state where arithmetic processing for the error probability P is executed (see step **S10**) and it is determined that the calculated error probability P is greater than or equal to the predetermined threshold value (see step **S11**), continues, the previously-discussed processing of steps **S14**-**S17** is repeatedly executed, until such time that step **S15** has determined that the correlation coefficient R^2 of the regression line becomes greater than or equal to the predetermined threshold value.

In the embodiment, when voltages of single batteries **C1**, **C2**, . . . , CN exist in a voltage region different from a targeted equalization voltage V_{tar}, needed to equalize the voltages of the single batteries **C1**, **C2**, . . . , CN, a voltage difference ΔV among the single batteries **C1**, **C2**, . . . , CN is calculated. Additionally, in the embodiment, by finding a time-dependent change in the calculated voltage difference ΔV, the tendency of a change in voltage difference ΔV can be grasped. Thus, according to the embodiment, it is possible to precisely grasp the tendency of a change in voltage difference ΔV. Hence, it is possible to appropriately predict time when the assembled battery **100** becomes an abnormal state (for example, a state where use restrictions are required due to a battery capacity fall in one or two or more batteries of the single batteries constructing the assembled battery **100**). In particular, according to the embodiment, when the voltages of the single batteries **C1**, **C2**, . . . , CN exist in the voltage region different from the targeted equalization voltage V_{tar} by a predetermined voltage V_1 or more, the voltage difference ΔV is calculated. By executing processing for predicting time when the assembled battery **100** becomes an abnormal state, using the calculated data, it is possible to greatly reconcile the capacity adjustment and prediction for an abnormal state of the assembled battery **100**. That is, according to the embodiment, it is possible to execute processing for predicting time when the assembled battery **100** becomes an abnormal state without being affected by the capacity adjustment, while appropriately executing the capacity adjustment.

Also, in the embodiment, by reference to the SOC-section table illustrating the specified relationship shown in FIG. **4**, a SOC section S_{sec}, to which a SOC region, corresponding to each of terminal voltages of the single batteries **C1**, **C2**, . . . , CN when arithmetic calculation for the voltage-difference ΔV data has been executed, belongs, is determined based on the calculated voltage-difference ΔV data. Then, in the embodiment, processing for predicting time when the assembled battery **100** becomes an abnormal state is performed by using only the voltage-difference ΔV data belonging to the determined SOC section S_{sec} and by finding a time-dependent change in voltage-difference ΔV data belonging to the same SOC section S_{sec}. That is, in the embodiment, a time-dependent change in voltage-difference ΔV data is found every SOC sections S_{sec}, and whereby processing for predicting time when the assembled battery **100** becomes an abnormal state is performed. Thus, according to the embodiment, it is possible to appropriately compare voltage differences ΔV calculated every points of time by finding a time-dependent change in voltage difference ΔV, using only the voltage-difference ΔV data belonging to the same SOC section S_{sec}. Hence, it is possible to more precisely predict time when the assembled battery **100** becomes an abnormal state. Additionally, processing for predicting time when the assembled battery **100** becomes an abnormal state is performed by finding a time-dependent change in voltage difference ΔV every SOC sections S_{sec}, and thus it is possible to execute the processing for predicting time when the assembled battery **100** becomes an abnormal state, regardless of the discharged state of the assembled battery **100**. Hence, it is possible to execute the processing for predicting time when the assembled battery **100** becomes an abnormal state, without being influenced by the driver's use custom for the assembled battery **100**.

Furthermore, according to the embodiment, as shown in FIG. **4**, regarding the SOC regions in which the ratio of the terminal-voltage change with respect to the SOC change in the battery becomes large, the SOC range, constructing each of the SOC sections S_{sec}, is set to be narrowed, as the ratio increases. Conversely, regarding the SOC region in which the ratio of the terminal-voltage change with respect to the SOC change in the battery becomes small, the SOC range, constructing each of the SOC sections S_{sec}, is set to be widened, as the ratio decreases. Hence, it is possible to more greatly enhance the accuracy of comparison of the voltage-difference ΔV data belonging to the same SOC section S_{sec}. As a result, it is possible to enhance the accuracy of prediction of time when the assembled battery **100** becomes an abnormal state.

Additionally, according to the embodiment, in predicting time when the assembled battery **100** becomes an abnormal state, on the basis of a regression line, obtained by performing linear regression of the correlation of voltage-difference ΔV data with voltage-difference ΔV measurement times, the time when the voltage difference ΔV becomes greater than or equal to the predetermined threshold value ΔV_α, is predicted as the time when the assembled battery **100** becomes an abnormal state. Hence, it is possible to comparatively simply but precisely predict time when the assembled battery **100** becomes an abnormal state. In particular, according to the embodiment, when the correlation coefficient R^2 of the regression line is greater than or equal to the predetermined threshold value and thus the reliability of the regression line is assured enough, processing for predicting time when the assembled battery **100** becomes an abnormal state is executed. Hence, it is possible to enhance the reliability of the prediction processing.

Also, according to the embodiment, in the case that the voltage difference ΔV is sharply increasing and hence the correlation coefficient R^2 of the regression line becomes low, the consecutive voltage-difference data for three points or more, whose error probabilities P become greater than or equal to the predetermined threshold value, are acquired and then another regression line is newly calculated. Processing for predicting time when the assembled battery **100** becomes an abnormal state is executed by the use of the newly calculated regression line. Thus, it is possible to more appropriately predict time when the assembled battery **100** becomes an abnormal state.

In the exemplified system configuration of the previously-described embodiment, voltage differences ΔV, calculated at all SOC sections S_{sec} of the SOC sections S_{sec} shown in FIG. **4**, are stored, and processing for predicting time when the assembled battery **100** becomes an abnormal state is executed every SOC sections S_{sec}. In lieu thereof, only the voltage differences ΔV, calculated at some SOC sections S_{sec} selected from the SOC sections S_{sec} shown in FIG. **4**, are stored. Then, processing for predicting time when the

assembled battery **100** becomes an abnormal state may be executed for each of the selected SOC sections S_{sec}. Concretely, only the voltage differences ΔV, obtained at the SOC section S_{sec} corresponding to the SOC region in which the ratio of the terminal-voltage change with respect to the SOC change in the battery is greater than or equal to a predetermined ratio (that is, the SOC sections S_{sec} that the SOC range, constructing each of the SOC sections S_{sec}, is set to be narrowed) are stored. Then, processing for predicting time when the assembled battery **100** becomes an abnormal state may be executed by the use of these stored data. In particular, in the SOC region in which the ratio of the terminal-voltage change with respect to the SOC change in the battery is greater than or equal to the predetermined ratio, the voltage difference ΔV can be detected as a greater value for the same capacity difference (for example, see FIG. **10** described later), in comparison with the SOC region in which the ratio of the terminal-voltage change to the SOC change is low. Thus, in the case of the SOC region in which the ratio of the terminal-voltage change to the SOC change is high, it is possible to execute processing for predicting time when the assembled battery **100** becomes an abnormal state, with a high accuracy, in comparison with the SOC region in which the ratio of the terminal-voltage change to the SOC change is low. Hence, by adopting such a system configuration, it is possible to execute processing for predicting time when the assembled battery **100** becomes an abnormal state with a high accuracy, while ensuring a reduction in the number of data stored in the memory and a reduction of the operation load.

In this case, from a viewpoint that the previously-discussed effects can be more greatly enhanced, it is preferable to predict time when the assembled battery **100** becomes an abnormal state, using only the voltage differences ΔV obtained in the SOC section S_{sec}, corresponding to the SOC region in which the ratio of the terminal-voltage change to the SOC change of the battery is greater than or equal to the predetermined ratio, and different from the SOC section S_{sec} belonging to the targeted equalization voltage V_{tar}.

Furthermore, when the SOC section S_{sec}, to which the targeted equalization voltage V_{tar} belongs, exists in a SOC region near the full charge S_{FULL}, it is preferable to use only the voltage differences ΔV, obtained in the SOC section S_{sec} existing in a SOC region near the discharge lower limit S_{L_LIM}. Conversely when the SOC section S_{sec}, to which the targeted equalization voltage V_{tar} belongs, exists in a SOC region near the discharge lower limit S_{L_LIM}, it is preferable to use only the voltage differences ΔV, obtained in the SOC section S_{sec} existing in a SOC region near the full charge S_{FULL}. That is, it is more preferable to detect the voltage differences ΔV in the SOC region opposite to the SOC region of the SOC section S_{sec} to which the targeted equalization voltage V_{tar} belongs, and to predict time when the assembled battery **100** becomes an abnormal state, by the use of the voltage differences ΔV detected in this way. In this case, the voltage difference among the single batteries whose voltages have been equalized at the targeted equalization voltage V_{tar}, can be fully canceled. Hence, it is possible to remarkably enhance the accuracy of prediction in predicting time when the assembled battery **100** becomes an abnormal state, while ensuring a reduction in the number of data stored in the memory and a reduction of the operation load.

Second Embodiment

Next, the second embodiment of the invention is hereunder described.

The second embodiment is similar to the first embodiment except that, in the assembled battery system shown in FIGS. **1-2**, abnormality-time prediction processing is executed by a method described below.

The abnormality-time prediction processing of the second embodiment is hereinafter described.

FIGS. **8-9** are the flowchart illustrating the flow of the abnormality-time prediction processing of the second embodiment. The abnormality-time prediction processing, hereinafter described in detail, is initiated when turning on an ignition switch of the vehicle, on which the assembled battery system of the second embodiment is mounted, or when powering the vehicle's electrical systems by the charging-on system. The following processing is executed mainly by means of the prediction section **507** of the battery controller **500**.

First, at step S**101**, in the same manner as the previously-discussed step S**1** of the first embodiment, data acquisition for the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN, and the battery temperature is executed.

Then, at step S**102**, in the same manner as the previously-discussed step S**2** of the first embodiment, a check is made to determine whether the difference between the targeted equalization voltage V_{tar} set by the control section **505** and the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN is greater than or equal to the predetermined voltage V_1. When the difference between them is greater than or equal to the predetermined voltage V_1, the routine proceeds to step S**103**. Conversely when the difference between them is less than the predetermined voltage V_1, the current processing terminates and thus the routine returns again to step S**101**.

Then, at step S**103**, the voltage difference, corresponding to a finite difference among the terminal voltages of the single batteries C**1**, C**2**, . . . , CN, is normalized with respect to a prescribed SOC, so as to execute normalized voltage-difference calculation processing. Hereupon, as shown in FIG. **3**, in a lithium-ion battery cell, constructed by assembling positive-electrode materials and negative-electrode materials, and used or exemplified as each of the single batteries C**1**, C**2**, . . . , CN, has a property that a ratio of a terminal-voltage change with respect to a SOC change is not constant. Concretely, the lithium-ion battery has a property that a ratio of a terminal-voltage change with respect to a SOC change in the battery becomes large in a SOC region near a full charge S_{FULL} and in a SOC region near a discharge lower limit S_{L_LIM}, and becomes small in the other SOC region (i.e., a plateau region). For instance, as shown in FIG. **10**, assume that the single battery A whose terminal voltage is "V_a" in the plateau region and the single battery B whose terminal voltage is "V_b" in the plateau region exist. Even when the voltage difference (V_a−V_b) between them is comparatively small in the plateau region, terminal voltages of the respective single batteries become "V_a'" and "V_b'" in the SOC region near the discharge lower limit S_{L_LIM}, and hence the voltage difference (V_a'−V_b') between them becomes comparatively large. For the reasons discussed above, for instance, assume that two single batteries, having a certain given capacity difference ΔAh, exist. In such a case, for the same capacity difference ΔAh, the voltage difference between these two single batteries in the SOC region near the full charge S_{FULL} becomes a value different from that in the plateau region. In other words, for the same voltage difference ΔV, the capacity difference, represented in the SOC region near the full charge S_{FULL}, tends to differ from the capacity difference represented in the plateau region. Therefore, in the second embodiment, when calculating a voltage difference among the single batteries C**1**, C**2**, . . . , CN, normalized voltage-difference calculation processing for normalizing the voltage difference with respect to a prescribed SOC (hereinafter is referred to as "prescribed SOC_α") is executed. In this manner, the voltage difference among the single batteries C**1**, C**2**, . . . , CN, which voltage

difference has been normalized with respect to the prescribed SOC_α, is calculated as a normalized voltage difference.

By the way, the prescribed SOC_α is not limited but set to an arbitrary state of charge. In the shown embodiment, the prescribed SOC_α is set to a given SOC in SOC regions, in which a ratio of a terminal-voltage change with respect to a SOC change is large, concretely, in a SOC region near the full charge S_{FULL} or in a SOC region near the discharge lower limit S_{L_LIM}. By setting the prescribed SOC_α to a given SOC in a SOC region in which a ratio of a terminal-voltage change with respect to a SOC change is large, as can be appreciated from the diagram of FIG. **10**, it is possible to calculate the obtained normalized voltage difference as a comparatively large difference. Hence, it is possible to more greatly enhance the accuracy of calculation processing when calculating a regression line of the normalized voltage difference at steps **S106**-**S109** described later, and thus it is possible to more greatly enhance the accuracy of processing for predicting time when the assembled battery **100** becomes an abnormal state.

Additionally, the prescribed SOC_α can be set to a given SOC in a SOC region near the discharge lower limit S_{L_LIM} when the targeted equalization voltage V_{tar} exists in a SOC region near the full charge S_{FULL}/and also set to a given SOC in a SOC region near the full charge S_{FULL} when the targeted equalization voltage V_{tar} exists in a SOC region near the discharge lower limit S_{L_LIM}. That is, the prescribed SOC_α can be set to a given SOC of the SOC region opposite to the SOC region of the targeted equalization voltage V_{tar}.

A calculation processing method for the normalized voltage difference among the single batteries **C1**, **C2**, . . . , CN is hereinafter described by reference to the flowchart shown in FIG. **11**.

First, at step **S201** shown in FIG. **11**, detection processing is carried out for detecting, based on the terminal voltages of the single batteries **C1**, **C2**, . . . , CN, acquired at step **S101** shown in FIG. **8**, both the highest voltage V_{max} of the single battery whose terminal voltage becomes the maximum value and the lowest voltage V_{min} of the single battery whose terminal voltage becomes the minimum value.

At step **S202**, calculation processing is carried out for calculating, from the highest voltage V_{max} and the lowest voltage V_{min} both detected at step **S201** and the battery temperature acquired at step **S101**, a SOC (hereinafter referred to as "SOC_{max}") of the single battery having the highest voltage V_{max} and a SOC (hereinafter referred to as "SOC_{min}") of the single battery having the lowest voltage V_{min}, on the basis of the table of FIG. **3** stored in the SOC table storage section **510** and showing the relationship between a SOC and a terminal voltage of each single battery **C1**, **C2**, . . . , CN. By the way, the battery has a property that the relationship between a SOC and a terminal voltage of each single battery **C1**, **C2**, . . . , CN generally depends on a battery temperature. In calculating the SOC_{max} and the SOC_{min} in the calculation processing for the normalized voltage difference in the embodiment, the calculation processing is made on the basis of the table of FIG. **3** showing the relationship between a SOC and a terminal voltage of each single battery **C1**, **C2**, . . . , CN, fully taking account of the battery temperature acquired at step **S101**.

At step **S203**, a capacity difference ΔAh between the single battery having the highest voltage V_{max} and the single battery having the lowest voltage V_{min} is calculated based on the SOC_{max} and the SOC_{min} both calculated at step **S202**. For instance, the capacity difference ΔAh can be calculated by multiplying a battery capacity (a rated capacity or an actual capacity) of each of the single batteries **C1**, **C2**, . . . , CN constructing the assembled battery **100** with the difference between the SOC_{max} and the SOC_{min} both calculated at step **S202**.

At step **S204**, a normalized capacity difference ΔAh_{nor}, corresponding to the difference capacity between the SOC of the single battery having the lowest voltage V_{min} and the prescribed SOC_α, is calculated from the SOC of the single battery having the lowest voltage V_{min} and the prescribed SOC_α, on the basis of the table of FIG. **3** showing the relationship between a SOC and a terminal voltage of each single battery **C1**, **C2**, . . . , CN. Then, a voltage (hereinafter referred to as "normalized lowest voltage V_{min_nor}") of the single battery having the lowest voltage V_{min} on the assumption that the SOC of the single battery having the lowest voltage V_{min} is the prescribed SOC, is calculated from the normalized capacity difference ΔAh_{nor} on the basis of the table of FIG. **3** showing the relationship between a SOC and a terminal voltage of each single battery **C1**, **C2**, . . . , CN. Referring to FIG. **12**, there is shown the explanatory diagram illustrating the calculation processing for the normalized voltage difference. That is, at step **S204**, as shown in FIG. **12**, the terminal voltage of the single battery having the lowest voltage V_{min} is normalized with respect to the prescribed SOC_α, so as to calculate the normalized lowest voltage V_{min_nor}.

At step **S205**, on the basis of the SOC of the single battery having the highest voltage V_{max} and the table of FIG. **3** showing the relationship between a SOC and a terminal voltage of each single battery **C1**, **C2**, . . . , CN, a voltage and a SOC of the single battery having the highest voltage V_{max}, after having subtracted the normalized capacity difference ΔAh_{nor}, calculated at step **S204**, from the capacity of the single battery having the highest voltage V_{max}, are calculated. The voltage and the SOC of the single battery having the highest voltage, calculated after the aforementioned subtraction, are hereinafter referred to as "normalized highest voltage V_{max_nor}" and "normalized SOC_{max_nor}", respectively. That is, at step **S205**, as shown in FIG. **12**, the terminal voltage of the single battery having the highest voltage V_{max} is normalized with respect to the normalized capacity difference ΔAh_{nor}, so as to calculate the normalized highest voltage V_{max_nor}.

At step **S206**, a normalized voltage difference ΔV_{nor} is calculated based on the normalized lowest voltage V_{min_nor} calculated at step **S204**, and the normalized highest voltage V_{max_nor}, calculated at step **S205**. Concretely, the normalized voltage difference ΔV_{nor} is calculated as a finite difference between the normalized highest voltage V_{max_nor} and the normalized lowest voltage V_{min_nor}.

In this manner, calculation processing for the normalized voltage difference ΔV_{nor} among the single batteries **C1**, **C2**, . . . , CN is executed. The normalized voltage difference ΔV_{nor}, calculated as discussed above, is a normalized value that the voltage difference, corresponding to the capacity difference ΔAh between the single battery having the highest voltage V_{max} and the single battery having the lowest voltage V_{min}, is normalized with respect to the prescribed SOC_α. Hence, the normalized voltage difference enables comparison between data measured in different SOC regions.

Returning again to FIG. **8**, at step **S104**, the voltage-difference data storage section **508** of the battery controller **500** executes processing for storing the normalized voltage-difference ΔV_{nor} data, calculated by the normalized voltage-difference calculation processing, in the voltage-difference data storage section **508**. At this time, the normalized voltage-difference ΔV_{nor} data, together with the measure-

ment-time data for the terminal voltage of each of the single batteries C1, C2, . . . , CN, used for arithmetic calculation for the normalized voltage difference ΔV, is stored in the memory incorporated in the battery controller **500**. In the second embodiment, the voltage-difference data storage section **508** is configured to store the normalized voltage-difference ΔV_{nor} data in the memory incorporated in the battery controller **500**, without executing correlation processing as executed in the first embodiment for correlating with the SOC section S_{sec}.

At step S**105**, the normalized voltage-difference ΔV_{nor} data, stored in the voltage-difference data storage section **508** and calculated by the arithmetic processing executed before the previous execution cycle (arithmetic processing until now) is read out, while correlating with the measurement time.

At step S**106**, in the same manner as the previously-discussed step S**6** of the first embodiment, by performing linear regression of the correlation of the normalized voltage-difference ΔV_{nor} data calculated by the arithmetic processing executed before the previous execution cycle, and the normalized voltage-difference ΔV_{nor} data calculated by the arithmetic processing executed by the current arithmetic processing, with the measurement times of these data, a regression line is obtained.

Then, at step S**107**, in the same manner as the previously-discussed step S**7** of the first embodiment, a check is made to determine whether a correlation coefficient R^2 of the regression line is greater than or equal to the predetermined threshold value. When the correlation coefficient R^2 is greater than or equal to the predetermined threshold value, the routine proceeds to step S**108** and thus an error flag is set to "0". Then, at step S**109**, in the same manner as the previously-discussed step S**9** of the first embodiment, processing for predicting time when the assembled battery **100** becomes an abnormal state is performed by calculating time when the normalized voltage difference ΔV_{nor} becomes greater than or equal to the predetermined threshold value ΔV_{α}.

Conversely when step S**107** determines that the correlation coefficient R^2 of the regression line is less than the predetermined threshold value, processing of steps S**110**-S**119** shown in FIG. **9** is executed. The processing of steps S**110**-S**119** shown in FIG. **9** is the same as that of steps S**10**-S**19** of the first embodiment shown in FIG. **6**. However, in the second embodiment, a single error flag can be set without setting an error flag every SOC sections S_{sec} and without executing such error processing as executed every SOC sections S_{sec} in the first embodiment, and also in the second embodiment such processing is executed for all voltage-difference ΔV data (regarding the error processing, each of the third and fourth embodiments described later are the same as the second embodiment). Also, after the processing of steps S**110**-S**119** shown in FIG. **9** has terminated, the current processing terminates and thus the routine returns again to step S**101**.

The second embodiment has the following merits in addition to the merits of the first embodiment.

That is, in the second embodiment, when calculating a voltage difference among the single batteries C1, C2, . . . , CN, a normalized voltage difference ΔV_{nor} that the SOC of each of the single batteries is normalized with respect to the prescribed SOC_{α}, is calculated. Time when the assembled battery **100** becomes an abnormal state is predicted by the use of the normalized voltage difference ΔV_{nor}. Hence, according to the second embodiment, it is possible to more greatly enhance the data compatibility between the voltage-difference data detected or measured in different SOC conditions, and whereby it is possible to compare the voltage-difference data with a high accuracy and thus it is possible to more precisely find a time-dependent change in voltage difference among the single batteries.

Third Embodiment

Next, the third embodiment of the invention is hereunder described.

The third embodiment is similar to the first embodiment except that, in the assembled battery system shown in FIGS. **1**-**2**, abnormality-time prediction processing is executed by a method described below.

The abnormality-time prediction processing of the third embodiment is hereinafter described.

FIG. **13** is the flowchart illustrating the flow of the abnormality-time prediction processing of the third embodiment. The abnormality-time prediction processing, hereinafter described in detail, is initiated when turning on an ignition switch of the vehicle, on which the assembled battery system of the third embodiment is mounted, or when powering the vehicle's electrical systems by the charging-on system. The following processing is executed mainly by means of the prediction section **507** of the battery controller **500**.

First, at step S**301**, in the same manner as the previously-discussed step S**1** of the first embodiment, data acquisition for the terminal voltage of each of the single batteries C1, C2, . . . , CN, and the battery temperature is executed.

Then, at step S**302**, in the same manner as the previously-discussed step S**2** of the first embodiment, a check is made to determine whether the difference between the targeted equalization voltage V_{tar} set by the control section **505** and the terminal voltage of each of the single batteries C1, C2, . . . , CN is greater than or equal to the predetermined voltage V_1. When the difference between them is greater than or equal to the predetermined voltage V_1, the routine proceeds to step S**303**. Conversely when the difference between them is less than the predetermined voltage V_1, the current processing terminates and thus the routine returns again to step S**301**.

At step S**303**, a check is made to determine, based on the terminal voltage of each of the single batteries C1, C2, . . . , CN, whether the SOC of each of the single batteries C1, C2, . . . , CN is within a predetermined SOC region S_r. When the SOC of each of the single batteries is within the predetermined SOC region S_r, the routine proceeds to step S**305**. Conversely when the SOC of each of the single batteries is outside of the predetermined SOC region S_r, the current processing terminates and thus the routine returns again to step S**301**. By the way, the predetermined SOC region S_r is not limited. In the shown embodiment, the predetermined SOC region S_r is set to a given SOC range in SOC regions, in which a ratio of a terminal-voltage change with respect to a SOC change is large, concretely, in a SOC region near the full charge S_{FULL} or in a SOC region near the discharge lower limit S_{L_LIM}. Also, in the shown embodiment, when the SOC, corresponding to the targeted equalization voltage V_{tar} set by the control section **505**, exists in a SOC region near the full charge S_{FULL}, the aforementioned predetermined SOC region S_r is set to a SOC region near the discharge lower limit S_{L_LIM}. Conversely when the SOC, corresponding to the targeted equalization voltage V_{tar} set by the control section **505**, exists in a SOC region near the

discharge lower limit S_{L_LIM}, the aforementioned predetermined SOC region S_r is set to a SOC region near the full charge S_{FULL}.

Then, at step S304, in the same manner as the previously-discussed step S3, the voltage difference ΔV, corresponding to a finite difference among the terminal voltages of the single batteries C1, C2, . . . , CN, is calculated.

Then, at step S305, the voltage-difference data storage section 508 of the battery controller 500 executes processing for storing the voltage-difference ΔV data, calculated at step S304, in the voltage-difference data storage section 508. At this time, the voltage-difference ΔV data, together with the measurement-time data for the terminal voltage of each of the single batteries C1, C2, . . . , CN, used for arithmetic calculation for the voltage difference ΔV, is stored in the memory incorporated in the battery controller 500. In the third embodiment, the voltage-difference data storage section 508 is configured to store the voltage-difference ΔV data in the memory incorporated in the battery controller 500, without executing correlation processing as executed in the first embodiment for correlating with the SOC section S_{sec}.

At step S306, the voltage-difference ΔV data, stored in the voltage-difference data storage section 508 and calculated by the arithmetic processing executed before the previous execution cycle (arithmetic processing until now) is read out, while correlating with the measurement time.

At step S307, in the same manner as the previously-discussed step S6 of the first embodiment, by performing linear regression of the correlation of the voltage-difference ΔV data calculated by the arithmetic processing executed before the previous execution cycle, and the voltage-difference ΔV data calculated by the arithmetic processing executed by the current arithmetic processing, with the measurement times of these data, a regression line is obtained.

Then, at step S308, in the same manner as the previously-discussed step S7 of the first embodiment, a check is made to determine whether a correlation coefficient R^2 of the regression line is greater than or equal to the predetermined threshold value. When the correlation coefficient R^2 is greater than or equal to the predetermined threshold value, the routine proceeds to step S309 and thus an error flag is set to "0". Then, at step S310, in the same manner as the previously-discussed step S9 of the first embodiment, processing for predicting time when the assembled battery 100 becomes an abnormal state is performed by calculating time when the voltage difference ΔV becomes greater than or equal to the predetermined threshold value ΔV_α.

Conversely when step S308 determines that the correlation coefficient R^2 of the regression line is less than the predetermined threshold value, the processing of steps S110-S119 shown in FIG. 9 as previously discussed in the second embodiment is executed. However, in the third embodiment, in steps S110-S119, the voltage difference ΔV is used instead of the normalized voltage difference ΔV_{nor}. Also, after the processing of steps S110-S119 shown in FIG. 9 has terminated, the current processing terminates and thus the routine proceeds to step S301.

The third embodiment has the following merits in addition to the merits of the first embodiment.

That is, in the third embodiment, when the SOC of each of single batteries is within the predetermined SOC region S_r, the voltage difference ΔV is calculated. Processing for predicting time when the assembled battery 100 becomes an abnormal state is executed by the use of the calculated voltage difference ΔV. Hence, it is possible to execute processing for predicting time when the assembled battery 100 becomes an abnormal state with a high accuracy, while ensuring a reduction in the number of data stored in the memory and a reduction of the operation load.

By the way, in the third embodiment, when the targeted equalization voltage V_{tar} exists in a SOC region near the full charge S_{FULL}, the predetermined SOC region S_r is set to a SOC region near the discharge lower limit S_{L_LIM}. Conversely when the targeted equalization voltage V_{tar} exists in a SOC region near the discharge lower limit S_{L_LIM}, the predetermined SOC region S_r is set to a SOC region near the full charge S_{FULL}. That is, the predetermined SOC region S_r can be set to the SOC region opposite to the SOC region of the targeted equalization voltage V_{tar}. In this case, the voltage difference among the single batteries whose voltages have been equalized at the targeted equalization voltage V_{tar}, can be fully canceled. Hence, it is possible to remarkably enhance the accuracy of prediction in predicting time when the assembled battery 100 becomes an abnormal state, while ensuring a reduction in the number of data stored in the memory and a reduction of the operation load.

Fourth Embodiment

Next, the fourth embodiment of the invention is hereunder described.

The fourth embodiment is similar to the first embodiment except that, in the assembled battery system shown in FIGS. 1-2, abnormality-time prediction processing is executed by a method described below.

The abnormality-time prediction processing of the fourth embodiment is hereinafter described.

FIG. 14 is the flowchart illustrating the flow of the abnormality-time prediction processing of the fourth embodiment.

In the fourth embodiment, as shown in FIG. 14, as a result of determination on whether the difference between the targeted equalization voltage V_{tar}, set by the control section 505 at step S2 as previously discussed in the first embodiment, and the terminal voltage of each of the single batteries C1, C2, . . . , CN is greater than or equal to the predetermined voltage V_1, in the case that the previously-noted difference is less than the predetermined voltage V_1, the routine proceeds to step S400 at which a micro-short-circuit abnormality detection processing is executed for predicting, by virtue of detection of a micro short-circuit, time when the assembled battery becomes an abnormal state. Thus, the fourth embodiment is similar to the first embodiment except the micro-short-circuit abnormality detection processing. That is, in the fourth embodiment, as a result of determination on whether the difference between the targeted equalization voltage V_{tar}, set by the control section 505 at step S2, and the terminal voltage of each of the single batteries C1, C2, . . . , CN is greater than or equal to the predetermined voltage V_1, in the case that the previously-noted difference is greater than or equal to the predetermined voltage V_1, in the same manner as the previously-described first embodiment, the processing of steps S1-S9 and steps S10-S9 shown in FIG. 6 is executed.

Conversely when the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C1, C2, . . . , CN is less than the predetermined voltage V_1, on the one hand, it can be determined that each of the single batteries C1, C2, . . . , CN becomes in a state where the terminal voltages of the single batteries have already been equalized at the targeted equalization voltage V_{tar} (or in a state where there is a less charging/discharging action for each of the single batteries

after having been equalized). Hence, in this case, it can be usually considered that the terminal voltages of the single batteries C1, C2, . . . , CN become equalized. However, on the other hand, in the event that a micro shirt-circuit occurs in the single batteries, constructing the assembled battery **100**, it is assumed that the terminal voltage of the single battery, which has been micro-short-circuited, becomes low, as compared to the other single batteries. For this reason, in the fourth embodiment, when the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C1, C2, . . . , CN is less than the predetermined voltage V_1, the micro-short-circuit abnormality detection processing (described later) is executed for predicting time when the degree of a micro short-circuit becomes large and as a result the assembled battery becomes an abnormal state.

The micro-shirt-circuit abnormality detection processing for predicting, by virtue of detection of a micro short-circuit, time when the assembled battery becomes an abnormal state, is hereinafter described. FIGS. **15-16** are the flowchart illustrating the flow of the micro-short-circuit abnormality detection processing.

First, at step S**401** of FIG. **15**, in the same manner as the previously-discussed step S**3** of the first embodiment, a micro-short-circuit detection voltage difference ΔV, is arithmetically calculated by calculating a finite difference among the terminal voltages of the single batteries C1, C2, . . . , CN.

Then, at step S**402**, the voltage-difference data storage section **508** of the battery controller **500** executes processing for storing the micro-short-circuit detection voltage-difference ΔV_s data, calculated at step S**401**, in the voltage-difference data storage section **508**. At this time, the micro-short-circuit detection voltage-difference ΔV_s data, together with the measurement-time data for the terminal voltage of each of the single batteries C1, C2, . . . , CN, used for arithmetic calculation for the micro-short-circuit detection voltage difference ΔV_s, is stored in the memory incorporated in the battery controller **500**. In the micro-short-circuit abnormality detection processing, the micro-short-circuit detection voltage-difference ΔV_s data is stored in the memory incorporated in the battery controller **500**, without executing correlation processing for correlating with the SOC section S_{sec}.

At step S**403**, the micro-short-circuit detection voltage-difference ΔV_s data, stored in the voltage-difference data storage section **508** and calculated by the arithmetic processing executed before the previous execution cycle is read out, while correlating with the measurement time.

At step S**404**, in the same manner as the previously-discussed step S**6** of the first embodiment, by performing linear regression of the correlation of the micro-short-circuit detection voltage-difference ΔV_s data calculated by the arithmetic processing executed before the previous execution cycle, and the micro-short-circuit detection voltage-difference ΔV_s data calculated by the arithmetic processing executed by the current arithmetic processing, with the measurement times of these data, a regression line is obtained.

Then, at step S**405**, in the same manner as the previously-discussed step S**7** of the first embodiment, a check is made to determine whether a correlation coefficient R^2 of the regression line is greater than or equal to the predetermined threshold value. When the correlation coefficient R^2 is greater than or equal to the predetermined threshold value, the routine proceeds to step S**406** and thus a micro-short-circuit detection error flag is set to "0". Then, the routine proceeds to step S**407**.

At step S**407**, on the basis of the regression line obtained at step S**404**, processing for predicting time when the degree of a micro short-circuit becomes large and as a result the assembled battery becomes an abnormal state is executed. Concretely, extrapolation processing for the regression line, obtained at step S**404**, is executed. Time when the micro-short-circuit detection voltage difference ΔV_s becomes greater than or equal to a predetermined micro-short-circuit detection threshold value ΔV_β is calculated from the extrapolated regression line. The calculated time is set as the time when the degree of a micro short-circuit becomes large and as a result the assembled battery becomes an abnormal state. By the way, in the embodiment, the aforementioned threshold value ΔV_β can be set to an arbitrary value at which it can be determined that the degree of a micro short-circuit becomes large and as a result the assembled battery becomes an abnormal state, for example, the same value as the threshold value ΔV_α or an arbitrary value different from the threshold value ΔV_α. Information about the time when the degree of a micro short-circuit becomes large and as a result the assembled battery becomes an abnormal state, which time is predicted or obtained in this way, is sent from the prediction section **507** to the communication section **510**. Then, the information is sent via the communication section **510** to the wireless communication terminal such as a cellular phone that the user has, or the on-vehicle equipment installed on the vehicle, for supplying the information via the wireless communication terminal or the on-vehicle equipment to the user. Then, the micro-short-circuit abnormality detection processing terminates and thus the routine returns again to step S**1**.

Conversely when step S**405** determines that the correlation coefficient R^2 of the regression line is less than the predetermined threshold value, processing of steps S**408**-S**417** shown in FIG. **16** is executed. The processing of steps S**408**-S**417** shown in FIG. **16** is similar to that of steps S**110**-S**119** of the second embodiment shown in FIG. **9**, except that, in steps S**110**-S**119** of the second embodiment shown in FIG. **9**, the micro-short-circuit detection voltage difference ΔV_s is used instead of the normalized voltage difference ΔV_{nor}, and the micro-short-circuit detection error flag is used instead of the error flag. Also, after the processing of steps S**408**-S**417** shown in FIG. **16** has terminated, the micro-short-circuit abnormality detection processing terminates and thus the routine returns again to step S**1**.

The fourth embodiment has the following merits in addition to the merits of the first embodiment.

That is, when the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C1, C2, . . . , CN is less than the predetermined voltage V_1, a micro-short-circuit detection voltage difference ΔV_s is calculated. It is possible to appropriately predict time when the degree of a micro short-circuit becomes large and as a result the assembled battery becomes an abnormal state, different from an abnormal state being predictable in the first embodiment (for instance, a state where use restrictions are required due to a battery capacity fall in one or two or more batteries of the single batteries constructing the assembled battery **100**), by the use of the calculated micro-short-circuit detection voltage difference ΔV_s.

By the way, in the previously-discussed processing exemplified by the fourth embodiment, the micro-short-circuit abnormality detection processing is executed when the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C1, C2, . . . , CN is less than the predetermined voltage V_1.

Execution of micro-short-circuit abnormality detection processing is not limited to the fourth embodiment described herein. As a matter of course, such micro-short-circuit abnormality detection processing may be executed in the second and third embodiments. In such a modified case, the same operation and effects can be provided.

By the way, in the previously-described embodiments, the prediction section **507** corresponds to an internal state detection means and a prediction means of the invention. The voltage-difference data storage section **508** corresponds to a time-series data storage means of the invention. The capacity adjustment section **504** and the control section **505** correspond to a capacity adjustment means of the invention. The control section **505** also corresponds to a targeted voltage setting means. The SOC table storage section **510** corresponds to a SOC-voltage table storage means of the invention.

While the foregoing is a description of the embodiments carried out the invention, it will be understood that these embodiments are described for easy understanding of the invention and thus the invention is not limited to the particular embodiments shown and described herein, but that various design changes and modifications and equivalents, belonging to the scope or spirit of this invention may be included.

For instance, the previously-described embodiments are exemplified by prediction processing for predicting, based on a time-dependent change in voltage difference among the single batteries, time when the assembled battery **100** becomes an abnormal state. Instead of using a time-dependent change in the voltage difference, the system may be configured to predict, based on a time-dependent change in the SOC difference among the single batteries, a time-dependent change in the capacity difference among the single batteries, or a time-dependent change in the internal-resistance difference among the single batteries, time when the assembled battery **100** becomes an abnormal state. In particular, there is a specified correlation between a voltage difference and a SOC difference among the single batteries. For this reason, in the previously-described embodiments, when using a SOC difference instead of a voltage difference among the single batteries, almost the same system configuration can be adopted and hence it is very preferable.

Furthermore, in the previously-described embodiments, when the difference between the targeted equalization voltage V_{tar} and the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN is greater than or equal to (or less than) the predetermined voltage V_1, the voltage difference ΔV (or the micro-short-circuit detection voltage difference ΔV_s) is calculated. The system configuration is exemplified by prediction processing for predicting, based on this calculation result, time when the assembled battery **100** becomes an abnormal state. In lieu thereof, when the difference between the SOC corresponding to the targeted equalization voltage V_{tar} and the SOC of each of the single batteries C**1**, C**2**, . . . , CN is greater than or equal to (or less than) a predetermined value, the voltage difference ΔV (or the micro-short-circuit detection voltage difference ΔV_s) may be calculated, and then prediction processing may be executed for predicting, based on this calculation result, time when the assembled battery **100** becomes an abnormal state. Moreover, instead of directly comparing the targeted equalization voltage V_{tar} with the terminal voltage of each of the single batteries, when the time, elapsed from a point of time when each of the single batteries has been equalized at the targeted equalization voltage V_{tar}, becomes longer than or equal to (or shorter than) a predetermined time, it may be determined that the difference between the targeted voltage V_{tar} and the terminal voltage of each of the single batteries C**1**, C**2**, . . . , CN has been greater than or equal to (or less than) the predetermined voltage V_1, and thus the voltage difference ΔV (or the micro-short-circuit detection voltage difference ΔV_s) may be calculated, and then prediction processing may be executed for predicting, based on this calculation result, time when the assembled battery **100** becomes an abnormal state.

Furthermore, in predicting time when the assembled battery **100** becomes an abnormal state, the system may be configured as follows. That is, time-series voltage-difference data of other assembled batteries except the assembled battery **100** are acquired, and then processing for predicting time when the assembled battery **100** becomes an abnormal state is performed by reference to the time-series voltage-difference data of the other assembled batteries. In particular, by adopting such a system configuration, it is possible to collect statistical much information. Additionally, by the utilization of the information about the states of these other assembled batteries, an abnormal degree of the controlled assembled battery can be determined in advance, adequately taking account of the whole battery-state tendency including the current states of the other assembled batteries as well as the controlled assembled battery. Additionally, it is possible to predict time when the assembled battery **100** becomes an abnormal state with a high accuracy.

Also, in the exemplified system configurations of the previously-described embodiments, another regression line is newly calculated in the case that the consecutive voltage-difference data for three points or more, whose error probabilities P become greater than or equal to the predetermined threshold value, have been acquired. The condition for calculating another regression line is not limited to such a condition that the consecutive voltage-difference data for three points or more, whose error probabilities P become greater than or equal to the predetermined threshold value, have been acquired. For instance, the system may be configured such that another regression line is newly calculated when the consecutive voltage-difference data for four points or more, whose error probabilities P become greater than or equal to the predetermined threshold value, have been acquired or when the more consecutive voltage-difference data, whose error probabilities become greater than or equal to the predetermined threshold value, have been acquired.

Also, in the exemplified system configurations of the previously-described embodiments, the abnormality-time prediction processing is executed within the battery controller **500**. In lieu thereof, the system may be configured such that the previously-discussed abnormality-time prediction processing is executed by means of an external abnormality detection device. In this case, the external abnormality detection device may be configured to acquire the terminal voltage of each of the single batteries constructing the assembled battery **100** from the battery controller **500** via a wireless communication terminal such as a cellular phone that the user of the assembled battery **100** has, an on-vehicle equipment installed on the vehicle, or a networked charging equipment. Thereafter, the abnormality detection device detects, based on the acquired terminal-voltage information, a voltage difference among the single batteries under a prescribed condition, and executes processing for predicting, based on the detected voltage-difference data, time when the assembled battery **100** becomes an abnormal state, according to the method as discussed previously. Then, in such a system configuration, the prediction result is sent to

the cellular phone that the user of the assembled battery **100** has, or the on-vehicle equipment installed on the vehicle.

The invention claimed is:

1. A device for controlling an assembled battery system having an assembled battery provided with a plurality of single batteries, comprising:

the assembled battery;

a targeted voltage setting means for setting a targeted voltage to equalize voltages of the plurality of single batteries constructing the assembled battery;

a capacity adjustment means for adjusting a capacity such that the voltages of the plurality of single batteries constructing the assembled battery are equalized at the targeted voltage;

an internal state detection means for detecting terminal voltages or SOC of the plurality of single batteries and for detecting, based on the detected terminal voltages or the detected SOC, a voltage difference or a SOC difference among the plurality of single batteries as voltage-difference data or SOC-difference data;

a time-series data storage means for storing the voltage-difference data or the SOC-difference data, detected by the internal state detection means, in time-series; and

a prediction means for predicting, prior to an occurrence of a first abnormal state of the assembled battery, time when the first abnormal state occurs, based on (a) a time-dependent change in the voltage-difference data detected in a voltage region different from the targeted voltage by a predetermined voltage or more, or (b) a time-dependent change in the SOC-difference data detected in a SOC region corresponding to voltage region different from a targeted voltage by the predetermined voltage or more, among the voltage-difference data or the SOC-difference data stored in the time-series data storage means.

2. The device for controlling the assembled battery system as claimed in claim **1**, wherein:

the time-series data storage means has a SOC-section table that a SOC range of the single battery from a full charge to a discharge lower limit is classified into a plurality of SOC sections;

the time-series data storage means stores the voltage-difference data or the SOC-difference data detected by the internal state detection means in time-series, while correlating the detected voltage-difference data or the detected SOC-difference data with the SOC section corresponding to the SOC when having detected, based on the SOC-section table, the voltage-difference data or the SOC-difference data; and

the prediction means predicts the time when the assembled battery becomes the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data belonging to a same SOC section, among the voltage-difference data or the SOC-difference data.

3. The device for controlling the assembled battery system as claimed in claim **2**, wherein:

each of the plurality of SOC sections is set to narrow a SOC range, as a ratio of a voltage change with respect to a SOC change increases.

4. The device for controlling the assembled battery system as claimed in claim **3**, wherein:

the prediction means predicts the time when the assembled battery becomes the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data belonging to the same SOC section, among the voltage-difference data or the SOC-difference data belonging to the SOC section whose SOC range is less than or equal to a predetermined range.

5. The device for controlling the assembled battery system as claimed in claim **4**, wherein:

the prediction means predicts the time when the assembled battery becomes the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data belonging to the same SOC section, among the voltage-difference data or the SOC-difference data belonging to the SOC section whose SOC range is less than or equal to the predetermined range and which SOC section has the ratio of the voltage change with respect to the SOC change, which ratio is different from that of the SOC section to which the SOC corresponding to the targeted voltage belongs.

6. The device for controlling the assembled battery system as claimed in claim **1**, which further comprises:

a SOC-voltage table storage means for storing a table showing a relationship between the SOC and the terminal voltage of each of the plurality of single batteries,

wherein the internal state detection means calculates normalized terminal voltages by normalizing the SOC of each of the single batteries of the plurality of single batteries, subjected to detection, with respect to a prescribed SOC, using the table stored in the SOC-voltage table storage means when detecting the voltage-difference data, and then detects the voltage-difference data based on the normalized terminal voltages.

7. The device for controlling the assembled battery system as claimed in claim **6**, wherein:

the prescribed SOC for normalization is a given SOC in a SOC region in which a ratio of a voltage change with respect to a SOC change is greater than or equal to a predetermined value.

8. The device for controlling the assembled battery system as claimed in claim **7**, wherein:

the prescribed SOC for normalization is a given SOC in a SOC region in which the ratio of the voltage change with respect to the SOC change is greater than or equal to the predetermined value and which has the ratio different from the ratio of the voltage change with respect to the SOC change in the SOC region corresponding to the targeted voltage.

9. The device for controlling the assembled battery system as claimed in claim **1**, wherein:

the internal state detection means detects the voltage-difference data or the SOC-difference data in a SOC region in which a ratio of a voltage change with respect to a SOC change is greater than or equal to a predetermined value and which has the ratio different from the ratio of the voltage change with respect to the SOC change in the SOC region corresponding to the targeted voltage or in the voltage region corresponding to the SOC region.

10. The device for controlling the assembled battery system as claimed in claim **1**, wherein:

the prediction means predicts time when the assembled battery becomes a second abnormal state different from the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data detected in a voltage region in which a deviation of the terminal voltage with respect to the targeted voltage is less than the predetermined voltage or in a SOC region corresponding to the voltage region.

11. The device for controlling the assembled battery system as claimed in claim 1, wherein:

the prediction means obtains a regression line by performing linear regression of the time-dependent change in the voltage-difference data or the SOC-difference data stored in the time-series data storage means, and predicts the time when the assembled battery becomes the first abnormal state, based on the obtained regression line.

12. The device for controlling the assembled battery system as claimed in claim 10, wherein:

the prediction means obtains a regression line by performing linear regression of the time-dependent change in the voltage-difference data or the SOC-difference data stored in the time-series data storage means, and predicts the time when the assembled battery becomes the second abnormal state, based on the obtained regression line.

13. The device for controlling the assembled battery system as claimed in claim 12, wherein:

the prediction means determines a reliability of the regression line, and calculates, based on the regression line, time when the voltage difference or the SOC difference among the plurality of single batteries becomes greater than or equal to a predetermined threshold value when the reliability of the regression line is greater than or equal to a predetermined value, and then predicts the time that becomes more than the predetermined threshold value as the time when the assembled battery becomes the first abnormal state or the second abnormal state.

14. The device for controlling the assembled battery system as claimed in claim 13, wherein:

the prediction means determines whether the voltage-difference data or the SOC-difference data, deviating from a distribution of the other voltage-difference data or the other SOC-difference data by a predetermined value among the voltage-difference data or the SOC-difference data stored in the time-series data storage means, have been detected more than a predetermined number, when the reliability of the regression line is less than the predetermined value, and obtains a new regression line by performing linear regression of the time-dependent change in the voltage-difference data or the SOC-difference data, when the voltage-difference data or the SOC-difference data, deviating from the distribution of the other voltage-difference data or the other SOC-difference data by the predetermined value; and

the prediction means determines the reliability of the obtained new regression line, and calculates, based on the new regression line, time when the voltage difference or the SOC difference among the plurality of single batteries becomes greater than or equal to a predetermined threshold value when the reliability of the new regression line is greater than or equal to a predetermined value, and then predicts the time that becomes more than the predetermined threshold value as the time when the assembled battery becomes the first abnormal state or the second abnormal state.

15. The device for controlling the assembled battery system as claimed in claim 1, which further comprises:

a data-acquisition means for acquiring voltage-difference data or SOC-difference data among a plurality of single batteries of other assembled batteries different from the controlled assembled battery subjected to control of the control device,

wherein, in predicting the time when the controlled assembled battery becomes the abnormal state, the prediction means predicts by reference to the voltage-difference data or the SOC-difference data of the other assembled batteries, acquired by the data-acquisition means, and simultaneously determines an abnormal degree of the controlled assembled battery in advance, taking account of a whole battery-state tendency including current states of the other assembled batteries as well as the controlled assembled battery.

16. The device for controlling the assembled battery system as claimed in claim 1, which further comprises;

an information means for informing a user of information about the time when the assembled battery becomes the abnormal state, predicted by the prediction means, via a wireless communication terminal or an on-vehicle equipment.

17. A device for controlling an assembled battery system having an assembled battery provided with a plurality of single batteries, comprising:

the assembled battery;

a targeted voltage setting section configured to set a targeted voltage to equalize voltages of the plurality of single batteries constructing the assembled battery;

a capacity adjustment section configured to adjust a capacity such that the voltages of the plurality of single batteries constructing the assembled battery are equalized at the targeted voltage;

an internal state detector configured to detect terminal voltages or SOC of the plurality of single batteries and to detect, based on the detected terminal voltages or the detected SOC, a voltage difference or a SOC difference among the plurality of single batteries as voltage-difference data or SOC-difference data;

a time-series data storage memory configured to store the voltage-difference data or the SOC-difference data, detected by the internal state detector in time-series; and

a prediction section configured to predict, prior to an occurrence of a first abnormal state of the assembled battery, time when the first abnormal state occurs, based on (a) a time-dependent change in the voltage-difference data detected in a voltage region different from the targeted voltage by a predetermined a SOC region corresponding to a voltage region different from a targeted voltage by the predetermined voltage or more, among the voltage-difference data or the SOC-difference data stored in the time-series data storage memory.

18. The device for controlling the assembled battery system as claimed in claim 17, wherein:

the time-series data storage memory has a SOC-section table that a SOC range of the single battery from a full charge to a discharge lower limit is classified into a plurality of SOC sections;

the time-series data storage memory stores the voltage-difference data or the SOC-difference data detected by the internal state detector in time-series, while correlating the detected voltage-difference data or the detected SOC-difference data with the SOC section corresponding to the SOC when having detected, based on the SOC-section table, the voltage-difference data or the SOC-difference data; and

the prediction section predicts the time when the assembled battery becomes the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data belonging to

a same SOC section, among the voltage-difference data or the SOC-difference data.

19. The device for controlling the assembled battery system as claimed in claim **18**, wherein:

each of the plurality of SOC sections is set to narrow a SOC range, as a ratio of a voltage change with respect to a SOC change increases.

20. The device for controlling the assembled battery system as claimed in claim **19**, wherein:

the prediction section predicts the time when the assembled battery becomes the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data belonging to the same SOC section, among the voltage-difference data or the SOC-difference data belonging to the SOC section whose SOC range is less than or equal to a predetermined range.

21. The device for controlling the assembled battery system as claimed in claim **20**, wherein:

the prediction section predicts the time when the assembled battery becomes the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data belonging to the same SOC section, among the voltage-difference data or the SOC-difference data belonging to the SOC section whose SOC range is less than or equal to the predetermined range and which SOC section has the ratio of the voltage change with respect to the SOC change, which ratio is different from that of the SOC section to which the SOC corresponding to the targeted voltage belongs.

22. The device for controlling the assembled battery system as claimed in claim **17**, which further comprises:

a SOC-voltage table storage memory configured to store a table showing a relationship between the SOC and the terminal voltage of each of the plurality of single batteries,

wherein the internal state detector calculates normalized terminal voltages by normalizing the SOC of each of the single batteries of the plurality of single batteries, subjected to detection, with respect to a prescribed SOC, using the table stored in the SOC-voltage table storage memory when detecting the voltage-difference data, and then detects the voltage-difference data based on the normalized terminal voltages.

23. The device for controlling the assembled battery system as claimed in claim **22**, wherein:

the prescribed SOC for normalization is a given SOC in a SOC region in which a ratio of a voltage change with respect to a SOC change is greater than or equal to a predetermined value.

24. The device for controlling the assembled battery system as claimed in claim **23**, wherein:

the prescribed SOC for normalization is a given SOC in a SOC region in which the ratio of the voltage change with respect to the SOC change is greater than or equal to the predetermined value and which has the ratio different from the ratio of the voltage change with respect to the SOC change in the SOC region corresponding to the targeted voltage.

25. The device for controlling the assembled battery system as claimed in claim **17**, wherein:

the internal state detector detects the voltage-difference data or the SOC-difference data in a SOC region in which a ratio of a voltage change with respect to a SOC change is greater than or equal to a predetermined value and which has the ratio different from the ratio of the voltage change with respect to the SOC change in the SOC region corresponding to the targeted voltage or in the voltage region corresponding to the SOC region.

26. The device for controlling the assembled battery system as claimed in claim **17**, wherein:

the prediction section predicts time when the assembled battery becomes a second abnormal state different from the first abnormal state, based on the time-dependent change in the voltage-difference data or the SOC-difference data detected in a voltage region in which a deviation of the terminal voltage with respect to the targeted voltage is less than the predetermined voltage or in a SOC region corresponding to the voltage region.

27. The device for controlling the assembled battery system as claimed in claim **17**, wherein:

the prediction section obtains a regression line by performing linear regression of the time-dependent change in the voltage-difference data or the SOC-difference data stored in the time-series data storage memory, and predicts the time when the assembled battery becomes the first abnormal state, based on the obtained regression line.

28. The device for controlling the assembled battery system as claimed in claim **26**, wherein:

the prediction section obtains a regression line by performing linear regression of the time-dependent change in the voltage-difference data or the SOC-difference data stored in the time-series data storage memory, and predicts the time when the assembled battery becomes the second abnormal state, based on the obtained regression line.

29. The device for controlling the assembled battery system as claimed in claim **28**, wherein:

the prediction section determines a reliability of the regression line, and calculates, based on the regression line, time when the voltage difference or the SOC difference among the plurality of single batteries becomes greater than or equal to a predetermined threshold value when the reliability of the regression line is greater than or equal to a predetermined value, and then predicts the time that becomes more than the predetermined threshold value as the time when the assembled battery becomes the first abnormal state or the second abnormal state.

30. The device for controlling the assembled battery system as claimed in claim **29**, wherein:

the prediction section determines whether the voltage-difference data or the SOC-difference data, deviating from a distribution of the other voltage-difference data or the other SOC-difference data by a predetermined value among the voltage-difference data or the SOC-difference data stored in the time-series data storage memory, have been detected more than a predetermined number, when the reliability of the regression line is less than the predetermined value, and obtains a new regression line by performing linear regression of the time-dependent change in the voltage-difference data or the SOC-difference data, when the voltage-difference data or the SOC-difference data, deviating from the distribution of the other voltage-difference data or the other SOC-difference data by the predetermined value; and

the prediction section determines the reliability of the obtained new regression line, and calculates, based on the new regression line, time when the voltage difference or the SOC difference among the plurality of single batteries becomes greater than or equal to a predetermined threshold value when the reliability of the new regression line is greater than or equal to a predetermined value, and then predicts the time that becomes more than the predetermined threshold value as the time when the assembled battery becomes the first abnormal state or the second abnormal state.

31. The device for controlling the assembled battery system as claimed in claim **17**, which further comprises:

a data-acquisition section configured to acquire voltage-difference data or SOC-difference data among a plurality of single batteries of other assembled batteries different from the controlled assembled battery subjected to control of the control device,

wherein, in predicting the time when the controlled assembled battery becomes the abnormal state, the prediction section predicts by reference to the voltage-difference data or the SOC-difference data of the other assembled batteries, acquired by the data-acquisition section, and simultaneously determines an abnormal degree of the controlled assembled battery in advance, taking account of a whole battery-state tendency including current states of the other assembled batteries as well as the controlled assembled battery.

32. The device for controlling the assembled battery system as claimed in claim **17**, which further comprises:

an information section configured to inform a user of information about the time when the assembled battery becomes the abnormal state, predicted by the prediction section, via a wireless communication terminal or an on-vehicle equipment.

* * * * *